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EDITED BY
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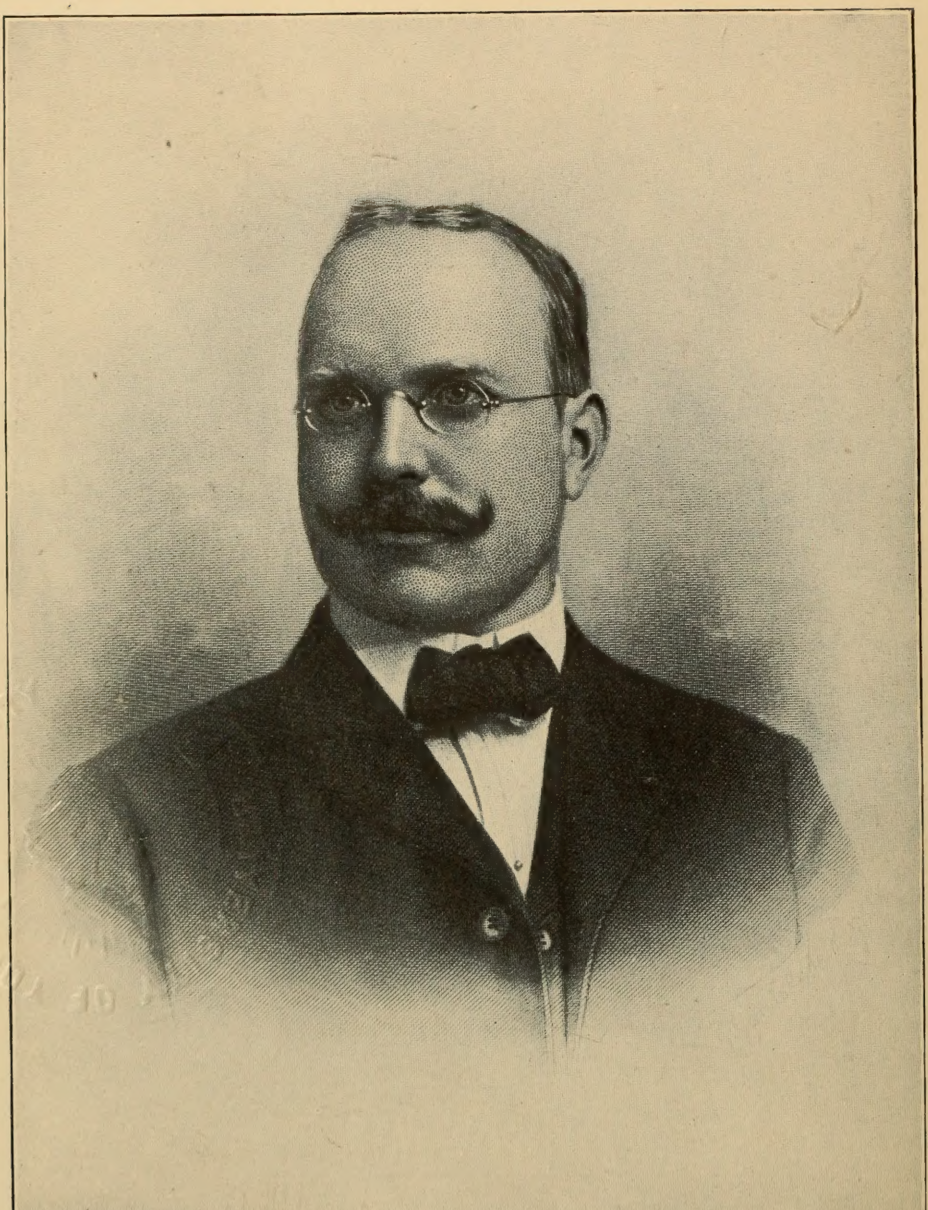

W. E. COREY

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The Iron and Steel Magazine

"...... *Je veux au mond publier d'une plume de fer sur un papier d'acier.*"

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AN INTRODUCTORY OUTLINE OF THE METALLURGY OF IRON AND STEEL *

By ALBERT SAUVEUR

BEFORE taking up the description of the early processes employed in the manufacture of iron and steel and of their subsequent development into the modern methods, it will be profitable to look into the conditions which must be fulfilled to extract metallic iron (or steel) from iron ores, and to consider briefly the most important chemical and physical principles involved in these operations — to take, so to speak, a bird's eye view of the subject which is to be treated somewhat at length in these pages.

Iron Ores. — By ores of iron are meant those iron-bearing minerals from which iron can be extracted on a commercial scale and at a profit. Although the minerals in which iron occurs are very numerous, the only ones from which the metal can be obtained under economical conditions — that is, the only ores of iron — are those in which iron is present as an oxide, as in magnetites, hematites and limonites; or as a carbonate, as in siderites, where the iron is combined with oxygen or with oxygen and carbon. Iron pyrites, which occur so abundantly,

* From advanced sheets of Volume II on "Iron and Steel" in a work of six volumes, entitled "National History of American Manufactures," soon to be published by the Van Slyck Publishing Company, of Boston.

cannot be utilized as an ore of iron owing to the large proportion of sulphur which they contain, for it will be seen that this element can only be eliminated partially and that it exerts a very injurious effect upon the properties of the metal.* When carbonate of iron, moreover, is heated to a sufficiently high temperature, either at an early stage of the process of manufacture itself or in a separate preliminary operation (the calcining of the ore), the carbonic acid which it contains is expelled as a gas and the iron is reduced to the condition of an oxide, hence the operation of extracting metallic iron from its ores; it consists in the deoxidation or reduction of oxide of iron.

The Reduction of Oxide of Iron. — In order to free iron from the oxygen with which it is chemically combined in the ore, thereby reducing it to the metallic state, we must bring the oxide of iron in contact with a substance which has more chemical affinity for oxygen than the iron itself, and by which, therefore, it will be deprived of its oxygen. Such a substance is said to be reducing or deoxidizing. Mere contact with a substance of this character, however, will not generally cause the iron to part with its oxygen. As in the case of so many other chemical phenomena, heat is required for the reaction to take place.

In order to reduce oxide of iron, therefore, two conditions at least must be met: (1) a high temperature and (2) contact with a reducing or deoxidizing substance.

The combustion of carbon in the shape of some carbonaceous fuel, solid or gaseous, naturally suggests itself as the means of obtaining the required temperature. Carbon, moreover, has a very great affinity for oxygen; it is a powerful reducing agent. By heating iron oxide, therefore, in contact with some carbonaceous fuel, the two conditions necessary to its reduction will be realized: carbon will act both as the needed fuel and as the needed reducing substance. The reduction of the oxide by the carbon of the fuel may be accomplished in two distinct ways: (1) The incandescent carbon may combine with the oxygen of the iron oxide, reducing it to the metallic state and

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* Iron pyrites are used in the manufacture of sulphuric acid, and the residue left after the extraction of the sulphur consists of an oxide of iron from which iron may be extracted, but the amount of iron derived from this source, compared to the total production of the metal, is very unimportant.

being itself converted into carbonic oxide gas, in which shape it escapes, or (2) the carbon may first combine with some oxygen from the air, being changed into carbonic oxide, which gas acts as the reducing agent, depriving the oxide of iron of its oxygen and being itself converted into carbonic acid gas.

These two reactions may be expressed as follows:

I. Reductions by solid carbon.

Iron oxide + solid carbon yields iron + carbonic oxide.

$$Fe_2O_3 + 3\,C = 2\,Fe + 3\,CO.$$

II. Reduction by carbonic oxide.

1. Carbon + oxygen yields carbonic oxide.

$$C + O = CO.$$

2. Iron oxide + carbonic oxide yields iron + carbonic acid.

$$Fe_2O_3 + 3\,CO = 2\,Fe + 3\,CO_2.$$

It is not indifferent, however, whether the reduction of the oxide is accomplished through the action of solid carbon or through that of the carbonic oxide gas resulting from a partial combustion of the carbon, for this consideration has an important bearing upon the relative value of the processes to be hereafter described.*

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* When carbonaceous fuel is allowed to burn in the air or with a sufficient supply of oxygen, each atom of carbon first combines with an atom of oxygen, the product of the reaction being carbonic oxide gas (CO), and its formation being accompanied by the production of heat.

$$C + O = CO.$$

In the condition of carbonic oxide, however, carbon is only partially burned; that is, it is still able to combine with an additional atom of oxygen, resulting in the production of carbonic acid gas (CO_2) and of an additional amount of heat.

$$CO + O = CO_2$$

When the reduction of the iron oxide, therefore, is accomplished by solid carbon the latter escapes only partially burned; each unit of carbon thus employed fails to yield all the heat which it was capable of producing. When the reduction is due to the action of carbonic oxide gas, on the contrary, each unit of carbon is fully burned, furnishing the maximum amount of heat before escaping. The reduction by carbonic acid gas is consequently more economical than the reduction by solid carbon. Under like conditions those processes in which the latter reaction prevails will consume more fuel. While complete reduction of the iron oxide by carbonic oxide gas, which would be an ideal condition, cannot be obtained in practice, it is the duty of the metallurgist to promote this reaction by all available means, so as to reduce to a minimum reduction by solid carbon, or in other words the escape of partially burned fuel.

If iron oxide then be heated to a sufficiently high temperature in contact with carbonaceous fuel, some metallic iron will be obtained.

Reduction of Iron Ore. — Iron ore never consists of pure oxide of iron. In the purest varieties the iron oxide is associated with at least a small amount of other minerals. These foreign substances are generally of an earthy character — that is, consisting of quartz, clay or limestone, and are called the *gangue* or *vein stuff*. In the majority of cases the gangue is silicious, which means that it is made up chiefly of silica or quartz. Silica is *per se* a very infusible or refractory compound, but when brought in contact with oxide of iron at a high temperature it combines with some of it to form a silicate of iron, a substance readily fusible:

Gangue (silica) + iron oxide yields slag (silicate of iron).

$$SiO_2 + FeO = FeO.SiO_2.$$

In metallurgical operations those compounds in which the gangue or other foreign matters are collected and thereby separated from the metal are called *slags*.

When iron ore, therefore, is heated in contact with some carbonaceous fuel, the iron oxide is reduced to the metallic state while the gangue combines with some of the iron to form a fusible silicate or slag. This may be expressed as follows:

Iron ore (iron oxide + gangue) + fuel yields iron + slag + gases.

$$Fe_2O_3 + SiO_2 + 2\,C = Fe + FeO.SiO_2 + 2CO.$$

Impurities. — Besides the earthy matters which constitute the gangue, iron ores generally contain other minerals in which are present such elements as phosphorus, sulphur, manganese, etc. Under the strongly reducing conditions required for the reduction of iron oxide, some of these elements as well as some of the silica of the gangue are partially reduced to the metallic state, in which condition they combine with the iron. The influence of these impurities upon the quality of the iron is generally harmful, especially so in the case of phosphorus and sulphur. Their elimination constitutes one of the most delicate problems of the steel metallurgist, and we shall have occasion to see that

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There are other considerations which indicate the greater economy of the reduction by carbonic oxide, but they cannot be dealt with here.

important special processes have been devised to that effect, especially for the removal of phosphorus.

Metallurgical fuels also generally contain such impurities as sulphur and phosphorus, and if they be used in contact with the reduced iron, these elements will in part be absorbed by the metal.

Affinity of Iron for Carbon. — When metallic iron is kept in contact with incandescent carbon for a sufficient length of time, some of the carbon is absorbed by the metal. The prevailing conditions are then said to be carburizing. This affinity of iron for carbon plays, as will soon be seen, a most important part in its metallurgy. Indeed, it is upon it that the manufacture of steel is based, for steel is merely iron containing a certain amount of carbon. The very great influence exerted by carbon upon the properties of iron will be referred to in another chapter, it being only desirable to call attention here to its effect upon the melting point of the metal. Pure, or, rather, carbonless iron requires a very high temperature to be melted (about 2900° F.), necessitating the use of special furnaces and implements capable of producing intense heat. By the introduction of some carbon in the iron, however, its melting point is greatly lowered. The important conclusion to be drawn from this action of carbon is that if the metal obtained in the metallurgical operation be highly carburized, it will be produced and maintained in a liquid state *much more readily than if it were freer from carbon.*

Primitive or Direct Methods. — The simple operation outlined in the preceding pages and consisting in heating iron ore in contact with carbonaceous fuel was the one conducted in the direct or primitive methods, which for ages were the only ones used for the production of iron and steel. Charcoal was the fuel employed, and the simple furnace required, called a forge or a bloomery, resembled a smith's forge. While these methods are now obsolete, having been replaced by the more modern indirect processes, they are still in use in some countries, although only to a very limited extent.

Product of the Direct Processes. — Owing both to a relatively low temperature and to a short time of contact between the reduced iron and the incandescent charcoal, the former absorbs generally very little carbon, the prevailing conditions not being carburizing. The metallic product of this simple operation will

consist, therefore, in a *pasty* mass of iron, generally quite free from carbon but retaining a certain amount of slag; in other words, it will be a lump of commercial wrought iron, for such is the nature of wrought iron, whose properties will soon be briefly described. This spongy lump of iron intermixed with slag is called a bloom from the Saxon word *blooma*, signifying metal, mass, lump. Hence the name of bloomeries given to the furnaces in which blooms are produced. The product of the forges and similar furnaces is called by the French *loop*, or *loup* (meaning wolf), and by the Germans *stück* (mass, piece, lump) and *wolf* (from the French word *loup*), the names of *stückofen* and of *wolfofen* being given by them to some of the furnaces in which these metallic sponges are obtained.

The direct process, however, may be so conducted as to cause the reduced iron to absorb more carbon, imparting thereby a steely character to the metal; for, as already mentioned, the essential difference between wrought iron and steel consists in a greater amount of carbon being generally present in the latter. This carburized iron was and is still frequently called steel, but the metallurgists of the present day are rightly reluctant to apply the name of steel to any carburized iron obtained in a pasty condition and therefore mixed with much slag, instead of being obtained molten, and consequently free from slag. Steely iron is a more appropriate term, and its use would prevent all possible confusion.

These methods are called direct because they yield iron by the direct treatment of the ore in a single operation, in contradistinction to the modern methods in which at least two distinct treatments are required for the production of iron and steel, the first operation yielding, as will be seen presently, an impure product called cast iron, which must be refined or purified in order to convert it into iron or steel.

Limitations of the Direct Processes. — It is quite evident that the direct methods as formerly practiced can only be applied profitably to very rich ores,— that is to ores quite free from gangue,— for if much gangue be present, as is generally the case, since the only available means of removing it consists in causing it to combine with some of the iron, the waste of metal from this source becomes so great as to preclude the use of the process. It has been stated, moreover, that when iron ore and solid fuel

are heated in contact, some of the impurities which may be present in the latter will be assimilated by the reduced iron, this being especially true of sulphur and phosphorus, and since these impurities are detrimental to the good quality of the iron, it becomes imperative to employ only very pure fuel, charcoal being the only available fuel sufficiently free from sulphur to be employed for the reduction of iron ores by the direct processes. Charcoal, however, is an expensive fuel and only available in a relatively small amount. A very large proportion of this expensive fuel is, moreover, needed per ton of iron. Finally the amount of labor required in the direct processes, per ton of iron produced, is very great. These considerations have led to the nearly complete abandonment of the direct methods for the production of iron and steel, for it is evident that the successful and profitable conduct of the process calls for an abundant and cheap supply of charcoal, an abundant supply of rich ore and cheap manual labor, a combination of circumstances seldom met with. The only redeeming feature of the direct method is that precisely because of the required purity of the raw materials, the resulting metal is also generally very pure and commands a higher price.

Fluxes. — In order to prevent the great waste of iron previously alluded to and resulting from the combination of the gangue of the ore with some of the metallic iron, it is necessary to provide a substance with which the silica of the gangue will readily unite, forming with it a fusible slag, and as silica is an acid it is necessary to provide a base to that effect.

Limestone (a carbonate of lime) is the most readily obtainable and cheapest substance for such purpose. It is either burned or calcined in a preliminary operation, by which it is converted into lime, the carbonic acid escaping as a gas, or if used raw, it is likewise changed to lime at an early stage of the metallurgical operation, by the heat to which it is exposed. The following equation represents this change:

$$\begin{array}{ccccc} \text{Limestone} & & \text{Lime} & & \text{Carbonic acid.} \\ CaCO_3 & = & CaO & + & CO_2. \end{array}$$

Lime is a powerful base readily combining with silica at a sufficiently high temperature, the resulting slag, a silicate of lime, being very free from iron.

The substances which are thus added for the purpose of

forming a fusible compound with the gangue of the ore or with other impurities are called fluxes. The reaction may be expressed as follows:

Flux (lime) + gangue (silica) yields slag (silicate of lime).

$$CaO + SiO_2 = CaO.SiO_2.$$

The use of fluxes constitutes one of the most important improvements ever introduced in the manufacture of iron, for it made it possible to extract the metal, under economical conditions, from the enormous amount of relatively lean ores which occur in nature, and to do so at a relatively very low cost. Previously to the use of fluxes it was unprofitable to treat ore containing less than some 60 per cent or 70 per cent of metallic iron, while with their assistance iron ores with as little as some 25 per cent of iron may be profitably smelted.

The Blast Furnace. — With the addition of lime, however, it is no longer possible to carry on the operation in the very simple furnace or forge previously used, because the resulting slag or silicate of lime is a much more infusible substance than the silicate of iron produced without the addition of lime. A sufficiently high temperature to fuse the lime slag cannot be produced in the forge furnace. If it were attempted to add lime in the forge in the hope of avoiding the passage of iron into the slag, the lime and the silica of the gangue would not combine, or only imperfectly, and in that case the resulting slag would not melt and could not, therefore, be separated from the metal.

The very high temperature required to fuse the lime slag necessitates the use of a very different type of furnace (a high, chimney-like furnace), together with the necessary appliances for the production of the needed heat; in other words, the reduction of the ore must be carried on in the modern blast furnace.

The Products of the Blast Furnace. — It has been seen that in the forge furnace the conditions were not favorable to the absorption of carbon by the iron and that the resulting pasty metallic mass was generally quite free from that element; or, in other words, that it consisted in a lump of wrought iron. The conditions prevailing in the blast furnace are of a very different character. Owing to the extremely high temperature at which the operation must be conducted and to prolonged contact between the reduced iron and the incandescent carbonaceous fuel, the conditions are strongly carburizing; the metal absorbs a large

amount of carbon (generally between 3 per cent and 4 per cent). Moreover, owing to the fact that highly carburized iron is much more fusible (melting generally between 2100° and 2400° F.) than iron containing little carbon, and to the intense heat of the furnace, the extracted metal instead of being obtained in a semi-fused, pasty condition, will be perfectly liquid, and on account of its high specific gravity will settle at the bottom of the furnace. The slag also will be melted, and being lighter than the iron will float as a separate layer above the metallic bath. The molten slag and the molten iron are withdrawn separately from the furnace, thus effecting their complete separation.

This highly carburized iron produced in the blast furnace is called pig iron, or cast iron. For reasons previously alluded to it will also contain varying amounts of other impurities such as phosphorus, sulphur, silicon and manganese, generally present in the ore, fuel and fluxes. Owing principally to the large amount of carbon which it contains, the properties of cast iron, soon to be described briefly, are very different from those of wrought iron and of steel.

To sum up, if ore, fuel and flux in suitable proportions are charged into a blast furnace, molten cast iron and molten slag are produced, settling at the bottom of the furnace, while the gaseous products of the operation escape at the top.

This we may express thus:*

$$\begin{array}{ccccccccccc} \text{Iron ore (iron oxide} & + & \text{gangue)} & + & \text{flux} & + \text{fuel} & \text{yields} & \text{iron} & + & \text{slag} & + \text{gas.} \\ Fe_2O_3 & + & SiO_2 & + & CaO & + 3\,C & = & 2Fe & + & CaO.SiO_2 & + 3CO \end{array}$$

The very great influence here illustrated of the temperature at which the reduction of iron ores is conducted, upon the nature

* It should be understood that the reactions taking place in a blast furnace are far from being as simple as they are expressed here. It is only attempted in this chapter to merely indicate the nature of the most important reactions as an introduction to the following chapters in which the subject is discussed at greater length. The gangue of iron ores, for instance, always contains besides silica such bases and acids as alumina, magnesia, oxide of manganese, phosphoric acid, etc., and the resulting slag is not a single silicate of lime but essentially a double silicate of lime and alumina containing other bases, such as magnesia, oxide of manganese, oxide of iron, etc., as well as calcium sulphide. Again the gases escaping from the furnace contain also a large proportion of nitrogen and of carbonic oxide as well as some hydrogen and other volatile matters.

of the metal obtained, is one of the important basic facts which the student of iron metallurgy should carefully bear in mind.

Blast Furnace v. Forge. — As already noted, it is possible in the blast furnace (that is, with the addition of flux) to treat much leaner ores than in the forge furnace; the slag produced contains very little iron and the amount of manual labor per ton of iron is considerably less. Moreover, since the product of the blast furnace is an impure metal, which, as will be seen, must be refined in order to be converted into wrought iron or steel, it is not as imperative to use a very pure and therefore expensive fuel. While charcoal alone is sufficiently pure to be used in the forge, coke, a more impure (especially as to its sulphur content) but much cheaper fuel, is admirably adapted to reduction in the blast furnace. Finally, while in the forge the consumption of three or more tons of charcoal are required for the production of one ton of wrought iron, less than one ton of coke is generally sufficient for the production of one ton of cast iron in the blast furnace. These considerations all point to the much greater economy of the latter furnace. It is true that the product of the blast furnace is an impure metal, which although used as such for some purposes (manufacture of cast-iron castings), must be subjected to a refining operation if we desire to obtain wrought iron or steel; but the combined cost of the blast furnace and of the refining operation is, under normal conditions, much less than the cost of the single operation of the direct processes.

The Refining of Cast Iron, or the Indirect Methods for the Production of Iron and Steel. — Cast iron is not malleable — it cannot be forged; that is, it cannot be shaped into finished implements by mechanical pressure such as is exerted by hammering, rolling, etc. Cast iron, therefore, can only be used as such for casting purposes, which means that cast-iron implements can only be obtained by pouring the molten metal into molds having exactly or very nearly the external shape of the objects we desire to manufacture. Cast iron, moreover, is brittle and lacks both strength and toughness, which further greatly limits its useful applications. To produce a metal which is forgeable, which possesses more strength and toughness and other valuable properties absent in cast iron and, therefore,

a much more useful metal, it is necessary to subject cast iron to a refining operation, by which it is converted either into steel or into wrought iron.

This indirect method of producing iron and steel is the prevailing modern method, for, in spite of strenuous efforts made to improve the older or direct method, it remains by far the cheaper of the two.

The refining of cast iron or its conversion into wrought iron or steel consists essentially in eliminating a large proportion of the impurities which it contains, especially carbon and silicon. In order to expel these impurities we must bring the cast iron in contact with a substance, either solid or gaseous, possessing more affinity for them than the iron itself, and here again heat is required for such reaction to take place. Oxygen has a very great affinity both for carbon and silicon, and in general for the other impurities present in cast iron, and it is upon this element that we shall depend for the elimination of the impurities. We may for that purpose use either atmospheric oxygen or the oxygen of some compound which readily parts with it, that is, of oxydizing substances. The oxidizing agents generally used besides atmospheric oxygen are rich iron ore or rich slag from some previous operation, or the slag produced in the refining operation itself. These substances are composed essentially of oxide of iron, which is an oxidizing compound for it readily parts with some of its oxygen which is taken up by the carbon of the cast iron. It might be stated here that in all the refining processes in which solid pig iron is used, most of the silicon is generally oxidized and expelled during the melting period, mainly through the action of atmospheric oxygen, while it is upon the oxidizing action of the iron oxide just mentioned that we chiefly depend for the elimination of the carbon.

When cast iron in order to be purified is exposed at a sufficiently high temperature to the action of atmospheric oxygen or of some other oxidizing substance, the silicon which it contains combines with some oxygen, being converted to silica. Some of the iron itself will be oxidized and the resulting oxide of iron will in turn enter into combination with the silica to form a fusible silicate of iron or slag. These reactions may be expressed as follows:

1. Silicon + atmospheric oxygen yields silica.
$$Si + 2O = SiO_2.$$
2. Iron + atmospheric oxygen yields iron oxide.
$$Fe + O = FeO.$$
3. Silica + iron oxide yields slag (silicate of iron).
$$SiO_2 + FeO = FeO.SiO_2.$$

The slags produced in refining operations are, therefore, generally rich in iron, but as only a small amount is made, the loss from this source is not excessive.

The carbon present in the cast iron also combines with some atmospheric oxygen, or more frequently with some of the oxygen held by the slag or by some iron ore purposely added, and is converted into carbonic oxide or carbonic acid gas, in which condition it escapes from the furnace. By being deprived of its oxygen the iron ore added in some of these refining operations is reduced to the metallic state and incorporated into the refined metal. This oxidation of the carbon may be thus expressed:

1. Oxidation by atmospheric oxygen.
Carbon + atmospheric oxygen yields carbonic oxide.
$$C + O = CO.$$
2. Oxidation by iron oxide.
Carbon + iron oxide yields iron + carbonic oxide.
$$3C + Fe_2O_3 = 2Fe + 3CO.$$

The Products of the Refining of Cast Iron. — As was the case in the treatment of the ore, the nature of the metal resulting from the refining of cast iron will likewise greatly depend upon the temperature at which the operation is conducted. If the temperature be low the refined metal will be obtained in a semi-fused or pasty condition, and will on that account include a relatively large amount of slag, while it will generally be quite free from carbon. In other words, the product of the refining operation conducted under these conditions will be wrought iron; or, if the conditions be made slightly more carburizing, steely iron. These are the conditions prevailing in the old forge refining of cast iron as well as in the more modern puddling process for the manufacture of wrought iron, which methods will be described more at length in another chapter.

If, on the other hand, the refining operation be conducted at a higher temperature, the refined metal will be obtained in

a molten state and susceptible, therefore, of being cast into molds.

The refining operation may be arrested when the molten bath still retains the amount of carbon required in the grade of steel it is desired to manufacture, or the operation may be continued until practically the whole of the carbon has been eliminated, the necessary amount of that element being then reintroduced into the metal through suitable additions. The expediency of this mode of procedure will be shown on another occasion.

The production of steel under these conditions is conducted in the modern methods known as the Bessemer process and the Open-Hearth process, soon to be described more at length.

Summary. — Summing up in a very few words the glimpse which has been taken into the metallurgy of iron and steel, these metals may be obtained directly from the ore in a single operation, or they may be produced in a more indirect way by first extracting an impure metal or cast iron from the ore, and subjecting it to a refining operation. The direct methods, however, owing to their greater cost and other limitations, have been practically abandoned.

The determinative influence of the temperature prevailing during the treatment of the ore, as well as in the refining of cast iron, upon the nature of the resulting product is again illustrated in the following synopsis:

	Conditions prevailing during the treatment of the ore	Nature of resulting product	Conditions prevailing during the refining of cast iron	Nature of resulting product
Iron ore heated in contact with carbonaceous fuel.	Low temperature — short time of contact between the reduced iron and the incandescent fuel. (*Direct Processes.*)	Pasty mass of slightly carburized iron mixed with slag (*wrought iron*), or if more carbon (*steely iron*).		
	High temperature — prolonged contact between the reduced iron and the incandescent fuel. (*Blast Furnace.*)	Molten mass of highly carburized iron (*cast iron*).	Low temperature. — (*Fineries* and *Puddling Furnace.*)	Pasty mass of slightly carburized iron mixed with slag (*wrought iron*), or if more carbon (*steely iron*).
			High temperature. — (*Bessemer Converter* and *Open-Hearth Furnace.*)	Molten mass of carburized iron (*steel*).

The Cementation and the Crucible Processes. — It should be stated, before bringing this chapter to an end, that steel is also manufactured by two other methods to be described more at length later, namely by the cementation process and by the crucible process.

In the cementation method wrought iron, obtained by one of the methods previously outlined, is heated to a high temperature but below its melting point in contact with charcoal or some other carbonaceous matter. The iron by this treatment is made to absorb some carbon which converts it into what is called *cemented* or *blister* steel. This was for centuries the best method available for the production of high-grade steel, but in our modern practice it is generally carried on only as a preliminary step to the manufacture of crucible steel.

In the crucible method the cemented steel just alluded to is melted in crucible and cast, or the wrought iron itself is melted in crucible with some charcoal, producing the carburization and the fusion in a single operation, and doing away, therefore, with the cementation operation. In both cases the molten metal obtained is called crucible steel.

These methods of obtaining steel are still more indirect, for unless the wrought iron used be made by a direct process, the cementation process required three distinct operations, while the crucible process may include as many as four operations as follows: (1) Smelting of the iron, producing cast iron; (2) conversion of cast iron into wrought iron; (3) carburizing of the iron in the cementation furnace, and (4) melting of the cemented steel in crucibles.

RESEARCHES ON THE COMPARATIVE HARDNESS OF ACID AND BASIC OPEN-HEARTH STEEL AT VARIOUS TEMPERATURES, BY MEANS OF "BALL-TESTING" *

By J. A. BRINELL

Special Contributor to the Iron and Steel Magazine

THE test material selected in order to serve the purpose of the present researches consisted of two charges of open-hearth steel, the one acid, and the other basic, being otherwise of a similar chemical composition as follows:

The acid steel

C	Si	Mn	S	P
0.17	0.014	0.35	0.015	0.028

The basic steel

C	Si	Mn	S	P
0.17	0.014	0.35	0.015	0.009

As to the acid material, the tensile properties were found to be:

Yield point per square millimeter	21.80 tons
Ultimate stress per square millimeter	35.93 tons
Elongation in 50 millimeters	51 per cent
Elongation in 100 millimeters	38.2 per cent
Elongation in 180 millimeters	32.7 per cent

Out of those materials, a sufficient number of specimens were prepared so as to present the identical sectional dimension of 38 x 25 millimeters, while being besides, all of them, uniformly annealed at 850° C.

In order to obtain the respective testing temperatures, the various specimens were separately heated in an electric resistance furnace, the temperature of which was ascertained with a Le Chatelier electric pyrometer. The testing operation consisted in forcing a 15-millimeter ball into each specimen, at the uniform pressure of 2,000 kilogrammes.

* Received December 12, 1904.

The comparative results as to hardness, thus obtained, will appear from the following table and diagram:

Testing Temperature	Acid Steel, Charge No. 5367			Basic Steel, Charge No. 4611		
	Diameter of Impression	Hardness Number	Calc. ultimate stress	Diameter of Impression	Hardness Number	Calc. ultimate stress
0°C	5.20	91.2	35.8	5.30	87.5	34.4
100°C	5.20	91.2	35.8	5.35	85.8	33.6
200°C	5.30	87.5	34.4	5.45	82.5	32.4
300°C	4.80	107.5	42.2	5.10	95.	37.3
400°C	4.85	104.7	41.1	4.85	104.7	41.1
500°C	4.95	100.5	39.5	5.10	95.	37.3
600°C	5.95	68.6	26.9	6.10	65.4	25.7
700°C	8.15	35.2	13.8	8.40	33.	12.9
800°C	9.50	25.0	9.8	9.90	22.7	8.9
900°C	10.15	21.4	8.4	10.40	20.2	7.9
1000°C	11.15	17.1	6.7	11.50	15.8	6.2
1100°C	12.80	11.8	4.6	12.85	11.6	4.5
1200°C	14.75	6.9	2.7	14.75	6.9	2.7

On examining the above results, one will find that the acid, as well as the basic material, proves to be less hard at 200° C., than at any other temperature ranging from 0° up to 500° C. (inclusive).

In the "Zeitscrift des Vereines Deutscher Ingenieure" there appeared lately a very interesting account * by Prof. C. Bach, of a rather comprehensive series of tests dealing with the tensile properties of soft ingot metal at various temperatures ranging from 20° up to 400° C., according to which the respective average values thus obtained had proved to be:

At 20° C.............. 39.40 kilograms per square millimeter
At 200° C............. 46.38 kilograms per square millimeter
At 300° C............. 47.99 kilograms per square millimeter
At 400° C............. 38.8 kilograms per square millimeter

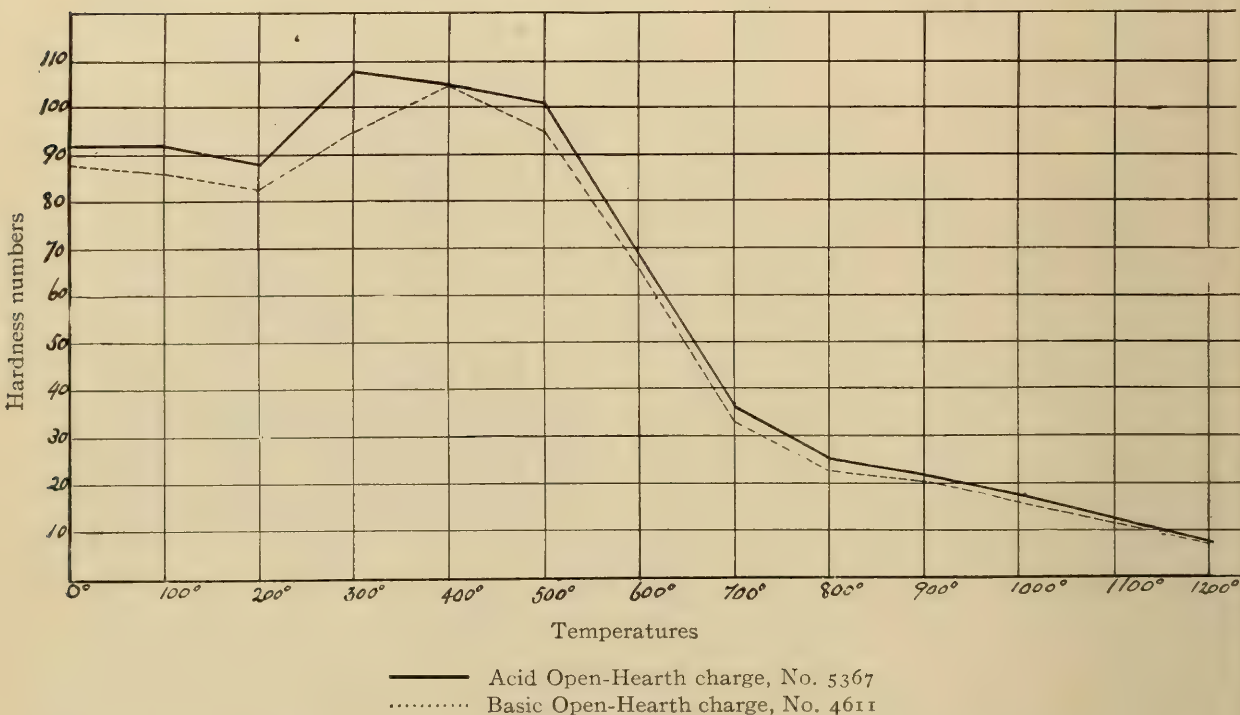
From these results it appears that there is a progressive increase in the value of ultimate stress, within the range of ascending temperatures from 20° C. up to some point between 300° and 400° C., beyond which the opposite tendency begins to prevail, the tenacity at 400° C. being considerably less than at 200° C., and even inferior to the value obtained at 20° C.

Bearing in mind that, in the case of soft and medium hard ingot metal, a constant relation has been found to exist, at ordinary temperature, between the value of the ultimate

* *Vid.* said periodical, No. 11, March 12, 1904.

stress and the hardness number,* it might have been expected that, conformably to Professor Bach's results, the hardness, as ascertained by means of ball-testing, should also have proved to be increased at 200° C.

Whether the discrepancy noted here is to be explained as being due either to different materials having been used in the two experiments, or to the relation between ultimate stress and hardness, assumed to be constant, but eventually varying at different temperatures, is a question only to be solved by means of further investigations.



In the last column of the above comparative table, one will find the respective values of ultimate stress at the various temperatures, these having been calculated from the hardness results by multiplying the respective hardness numbers by 0.393†, the relation between ultimate stress and hardness being thus assumed to be constant, regardless of the temperature.

We are often told that basic open-hearth steel should give

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* *Vid.* "Jernkontorets Annaler," 1903, p. 421.

† This coefficient, being here substituted for the one applying to tests by means of the 10-millimeter ball (=0.362), is as yet of a certain provisional character.

softer forging material than acid open-hearth steel. According to the present tests, it appears that, with almost identical chemical composition, the basic material will prove to be somewhat, although not very much, softer than the acid one.

THE DEVELOPMENT AND USE OF HIGH-SPEED TOOL STEEL*

By J. M. GLEDHILL

Introductory

IT would doubtless have been felt by many, but a few years back, that there was little left to be said on the subject for

crucible tool steel, and that something akin to finality had been arrived at in its manufacture and general treatment. Probably such feeling was justifiable when it is remembered that the making of steel in crucibles is by far the oldest method known, dating back from time immemorial, it being indeed impossible to accurately trace its origin and earliest development, but it seems certain that carbon steel was made and used thousands of years ago for cutting tools. Proof of this may be seen by the marvelous carvings and workings on the intensely hard stone work of the ancients, for it would be difficult

* The Iron and Steel Institute, New York meeting, October, 1904. The paper also includes an appendix dealing with some results obtained with high-speed steels.

Mr. J. M. Gledhill is a Member of Council of the Iron and Steel Institute, and the only son of an eminent engineer, — the late Mr. M. Gledhill, who was the managing director of Sir Joseph Whitworth & Company, Limited, Openshaw, Manchester, with whose establishment he was associated for over half a century. Mr. Gledhill, who may justly claim to have received an inheritance in engineering abilities from his father,

to conceive by what means, other than with steel tools, such work could have been executed, and it is wonderful to contemplate that steel-cutting tools should have been used so long ago, whilst the principle of manufacturing them — that is, by fusion of iron and charcoal in crucibles — was then in a measure on the same lines as we work on at the present day. Archeologists have discovered that the Chinese made steel in crucibles long before the Christian era.

"Wootz" steel, fabricated in India centuries ago, was crucible steel, as was also the celebrated Damascus steel, produced at the forges of Toledo, and, curiously, this latter steel furnishes yet another proof that "there is nothing new under the sun," for it is recorded that Damascus steel contained certain percentages of tungsten, nickel, manganese, etc., some of the very elements, in fact, contained in the present modern high-speed steel; so that a latent high-speed steel may be said to have existed centuries ago, and all that was necessary to bring out its inherent powers would have been the heating of it in a "paradoxical" manner, so to speak; that is, to such a high degree of temperature as was long thought would impair or destroy the nature of such steel. When, therefore, we look back on the period for

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studied at the Victoria University, where he was successful in obtaining the two Ashbury Scholarships for Civil and Mechanical Engineering, respectively. Mr. Gledhill was for many years one of his father's chief assistants in the works, finally becoming a director of Messrs. Whitworth & Company, Limited. On the amalgamation of the firm with that of Messrs. Armstrong, Mitchell & Company, Limited, some years back, Mr. Gledhill took charge of the steel works and also of the development and laying out of the armour-plate shops at Openshaw, which undoubtedly rank second to none for magnitude and perfection of plant and machine tools. The armour-plate rolling mill is most massive throughout, mostly built of forged steel, including the housings, which consist of huge armour plates each weighing 100 tons. The rolls are of nickel steel, 4 feet 2 inches diameter, and 14 feet on the face; whilst the mill engines are of the three-cylinder vertical marine type, having forged steel cylinders, and capable of exerting 10,000 horse-power. Working in conjunction with the mill are hydraulic presses, one of 12,000 tons pressure, for compressing the steel in the fluid state on the well-known Whitworth system, and the other a forging press, also of 12,000 tons pressure, for hydraulic forging. All of this plant, with engines, pumps and cranes is stupendous in its magnitude and strength. Mr. Gledhill has devoted much time to the study of modern high-speed steel, and has read several papers on the subject. — *Iron and Coal Trades Review, November 11, 1904.*

which crucible steel has been known to the world's history, some may not unnaturally think that there has been time enough to have fully fathomed its mysteries, leaving little more to be said on the subject. It is, then, all the more remarkable that a discovery, made but a few years back, and which has since revolutionized the treatment of crucible tool steel, should have remained so long a hidden secret.

A very important advance was made, thirty or forty years ago, when "Mushet," or self-hardening steel, was introduced. This was the valuable invention of Robert Mushet, who, after a long series of experiments, made whilst he was manager of the Titanic Steel Co., succeeded in producing a tungsten steel, and its introduction was a great advancement on the cutting powers of ordinary crucible steel, and for many years "Mushet" steel held a foremost place amongst tool steels.

It is now to America, however, that all honor must be given for the next great step in having "set the pace" and led the way in the present remarkable advancement in tool steel, and the author would here like to record that the greatest credit is due to Messrs. Taylor & White, who, at the Bethlehem Steel Works of America, initiated high-speed cutting, and at the exhibit of their firm in Paris, some few years back, what were then considered to be astonishing results in speeds of cutting steel were publicly demonstrated. Since then still greater developments have been made by the author's firm in high-speed steels, and with increased experience in its manufacture, treatment and application in our workshops, results in cutting powers far beyond expectation have been attained.

In those branches of the engineering world necessitating the use of tool steels in course of manufacture of their products, there is probably no section of greater importance thereto than that of the application and practical use of what is now known as "high-speed steel," and it may be said without doubt that no development in the annals of metallurgy has been more striking than the production of such steel, whilst the alacrity with which users have up to now appreciated and adopted high-speed cutting steel may be said to be almost comparable with the rapid powers of the steel itself. Perhaps this is not surprising when we look back and reflect that for many years past, previous to the advent of high-speed steel, practically but little advance had been made

in the cutting powers of tool steels, feeds and speeds remaining more or less in a normal condition, and it must undoubtedly have often appeared to users generally that the cutting powers of the ordinary tool steels were very slow, and that the turn-out of work could be greatly enhanced and economized if the cutting powers of tool steels could be substantially improved by some research of the metallurgist. Time has eventually realized those hopes to a large extent, and hence the desire now on all sides to use high-speed steel wherever possible. When it is seen that, with high-speed tools, steel can now be turned and machined at a rate up to 500 feet per minute, and cast iron drilled at 25 inches per minute, it must be admitted that this is an astonishing advancement on the cutting speeds of 30 to 50 feet per minute with ordinary crucible steel.

The production of steel capable of such cutting powers has not been obtained without exhaustive scientific research and trial, and the author may state that experiments have been made by him extending over a period of four years, during which time some eighty different compositions of high-speed steels were produced, and hundreds of trials made with them by actual cutting; and whilst some excellent results were obtained with many of them, others gave but indifferent ones.

In the manufacture and production of high-speed steels (the best being made by the crucible process) the author has proved conclusively that the most satisfactory results are obtained only by using the purest qualities of Swedish or Danemora irons, which on account of their freedom from impurities render them most suitable for producing tool steels that will best retain their cutting edges, and also the use of the highest qualities of the various alloys and other ingredients employed in the composition of the steel.

Special care is required in the melting and subsequent treatment of ingots alloyed with high percentages of other metals so as to insure homogeneity and regularity of quality, which is one of the most important points to be considered, for no permanent advantage or economy can be relied on if good results are obtained from one bar of steel and inferior results from the next, as will be the case where attention and experience are not exercised.

Summary of Results of Experiments

The high-speed steels of the present day are combinations of iron and carbon with (1) tungsten and chromium, (2) molybdenum and chromium, (3) tungsten, molybdenum and chromium. These present many interesting varieties, and offer a wide field for research. The author has made a large number of experiments to ascertain comparative cutting powers of steels produced by varying proportions of these elements, and it may be interesting to briefly state the results of some of those investigations.

Influence of Carbon. — A number of tool steels were made, the carbon percentage varying from 0.4 per cent to 2.2 per cent, and the method of hardening was to heat the steel to the highest possible temperature without destroying the cutting edge, and then rapidly cooling in a strong air blast. By this simple method of hardening it was found that the greatest cutting efficiency is obtained where the carbon ranges from 0.4 per cent to 0.9 per cent, and such steels are comparatively tough. Higher percentages are not desirable because great difficulty is experienced in forging the steels, and the tools are inferior. With increasing carbon contents the steel is also very brittle, and has a tendency to break with unequal and intermittent cutting.

Influence of Chromium. — Having thus found the best carbon content to range from 0.4 per cent to 0.9 per cent, the next experiments were made to ascertain the influence of chromium varying from 1.0 per cent to 6.0 per cent. Steels containing a low percentage are very tough, and perform excellent work on the softer varieties of steel and cast-iron, but when tried on harder materials the results obtained were not so efficient. With an increased content of chromium the nature of the steel becomes much harder, and greater cutting efficiency is obtained on hard materials. It was observed that with an increase of chromium there must be a decrease in carbon to obtain the best results for such percentage of chromium.

Mention may here be made of an interesting experiment to ascertain what effect would be produced in a rapid steel by substituting vanadium for chromium. The amount of vanadium present was 2.0 per cent. The steel readily forged, worked very tough, and was hardened by heating to a white heat and cooling

in an air blast. This tool when tried on medium steel stood well, but not better than the steel with the much cheaper element of chromium in it.

Influence of Tungsten. — This important element is contained in by far the greater number of the present high-speed steels in use. A number of experiments were made with the tungsten content ranging from 9.0 per cent to 27.0 per cent. From 9.0 per cent to 10.6 per cent the nature of the steel becomes very brittle, but at the same time the cutting efficiency is greatly increased, and about 16.0 per cent appeared to be the limit, as no better results were obtained by increasing the tungsten beyond this figure. Between 18.0 per cent and 27.0 per cent it was found that the nature of the steel altered somewhat, and, instead of being brittle, it became softer and tougher, and whilst such tools have the property of cutting very cleanly, they do not stand up so well.

Influence of Molybdenum. — The influence of this element at the present time is under investigation, and our experiments with it have so far produced excellent results, and it is found that where a large percentage of tungsten is necessary to make a good rapid steel, a considerably less percentage of molybdenum will suffice. A peculiarity of these molybdenum steels is that in order to obtain the greatest efficiency they do not require such a high temperature in hardening as do the tungsten steels, and if the temperature is increased above 1000° C. the tools are inferior, and the life shortened.

Influence of Tungsten with Molybdenum.— It was found that the presence of from 0.5 per cent to 3.0 per cent molybdenum in a high tungsten steel slightly increased the cutting efficiency, but the advantage gained is altogether out of proportion to the cost of the added molybdenum.

Influence of Silicon. — A number of rapid steels were made with silicon content varying from a trace up to 4.0 per cent. Silicon sensibly hardens such steels, and the cutting efficiency on hard materials is increased by additions up to 3.0 per cent. By increasing the silicon above 3.0 per cent, however, the cutting efficiency begins to decline. Various experiments were made with other metals as alloys, but the results obtained were not sufficiently good by comparison with the above to call for comment.

An analysis of one of the best qualities of rapid steels produced by the author's firm is as follows:

"A. W. Steel"

Carbon	0.55 per cent
Chromium	3.5 per cent
Tungsten	13.5 per cent

What may be said to determine a high-speed steel, as compared to an ordinary tool steel, is its capability of withstanding the higher temperatures produced by the greatly increased friction between the tool and the work due to the rapid cutting. An ordinary carbon steel, containing, say, 1.20 per cent carbon, when heated slightly above the critical point and rapidly cooled by quenching in water, becomes intensely hard. Such a steel gradually loses this intense hardness as the temperature of friction reaches, say, 500° F. The lower the temperature is maintained the longer will be the life of the tool, so that the cutting speed is very limited. With rapid cutting steels the temperature of friction may be greatly extended, even up to 1100° F. or 1200° F., and it has been proved by experience that the higher the temperature for hardening is raised above the critical point and then rapidly cooled, the higher will be the temperature of friction that the tool can withstand before sensibly losing its hardness. The high degree of heating (almost to melting point, in fact) which is necessary for hardening high-speed steel forms an interesting study in thermal treatment and is indeed a curious paradox, quite inverting all theory and practice previously existing. In the case of hardening ordinary carbon steels very rapid cooling is absolutely necessary, but with high-speed steels the rate of cooling may take a considerably longer period, the intensity of hardness being increased with the quicker rate of cooling.

In his admirable paper on "Rapid Steel for Tools,"* M. Le Chatelier states that "steel undergoes at 700° C. a change of nature which has been studied in all its details by M. Osmond. This transformation, like a great number of chemical transformations, takes place with more or less considerable delay according to certain other circumstances. *When heating*, the transformation will take place above 700° C., for example, from 750° to 800° C., according to the rapidity of heating. *When cooling*, below 700° C. the quickness with which this transforma-

Bulletin de la Sociétié d'Encouragement pour l'Industrie Nationale.

tion takes place at a given temperature is governed by a general law of chemical phenomena, and this rapidity is so much the greater, (1) As the absolute temperature in question is highest; (2) As it is at its greatest distance from the point of transformation."

It may be added that the transformation at the critical point takes only a very short time in the case of simple carbon steels, and the influence of such elements as chromium, tungsten, molybdenum, vanadium and manganese is to considerably retard this change.

Turning now to some points in the heat treatment of high-speed steel, one of the most important is the process of thoroughly

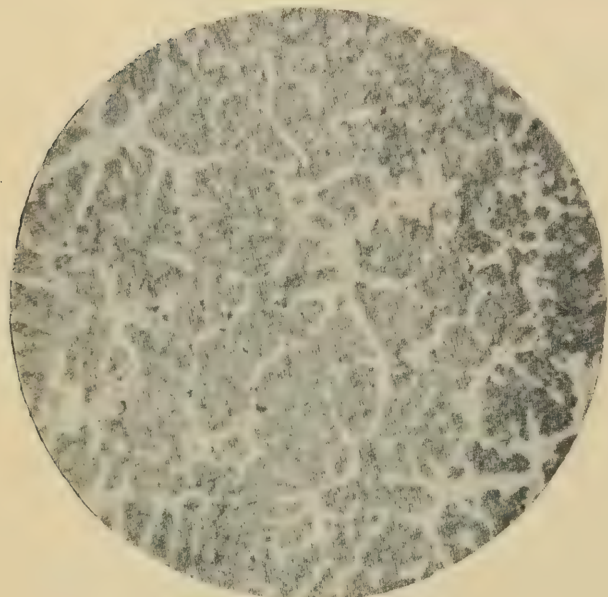

Fig. A. As Cast

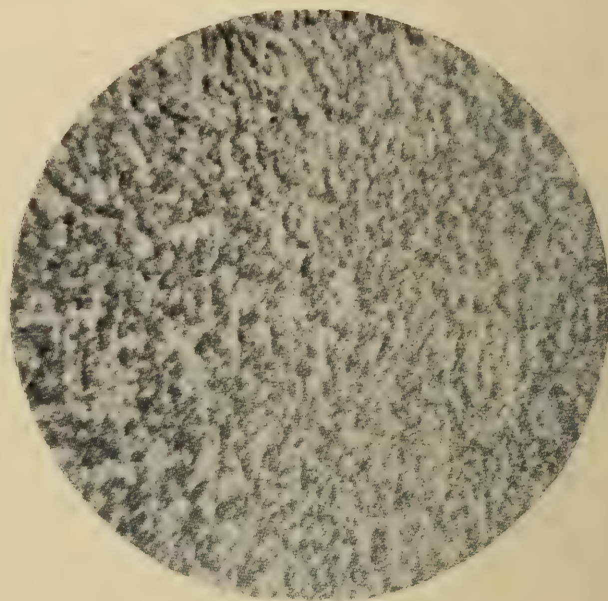

Fig. B. Normal Forged

annealing it after working into bars. Accurate annealing is of much value in bringing the steel into a state of molecular uniformity, thereby removing internal strains that may have arisen, due to casting and tilting, and at the same time annealing renders the steel sufficiently soft to enable it to be machined into any desired form for turning tools, milling cutters, drills, taps, screwing dies, etc.

The annealing of high-speed steel is best carried out in muffle furnaces designed for heating by radiation only, a temperature of 1400° F. being maintained from twelve to eighteen hours, according to the section of the bars of steel dealt with.

Further advantage also results from careful annealing by minimizing risks of cracking when the steel has to be reheated for hardening. In cases of intricately shaped milling tools

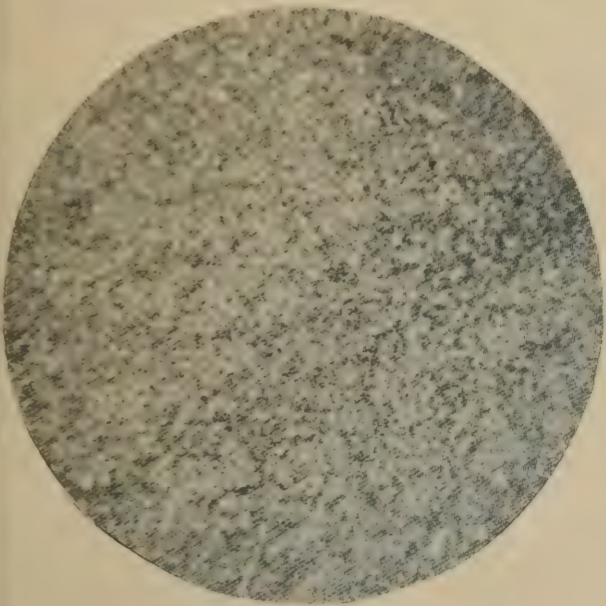

Fig. C. Annealed

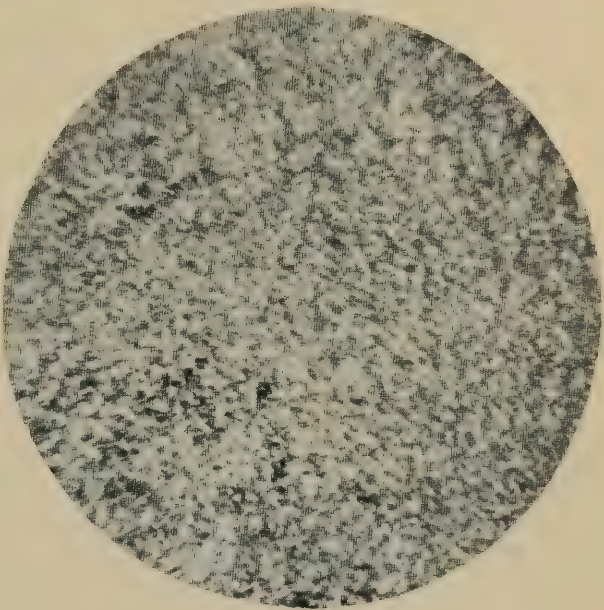

Fig. D. Oil Hardened

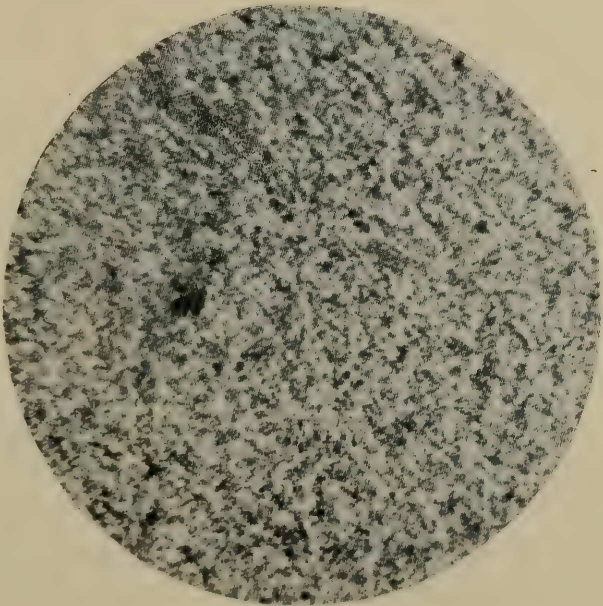

Fig. E. Oil Hardened and Tempered

having sharp, square bottom recesses, fine edges or delicate projections, and on which unequal expansion and contraction are

liable to operate suddenly, annealing has a very beneficial effect towards reducing cracking to a minimum.

Increased ductility is also imparted by annealing, and this is especially requisite in tools that have to encounter sudden shocks due to intermittent cutting, such as planing and slotting tools, or others suddenly meeting projections or irregularities on the work operated on.

The following tensile tests of "A. W." high-speed steel in the normal, annealed, hardened, and hardened and then tempered states, also the microscopic views given in Figs. A, B, C, D and E, and of the steels in the states described, will be instructive as showing the effects of the heat treatment.

No. of Specimen	Condition	Elastic limit, tons per sq. in.	Breaking strain, tons per sq. in.	Elongation, per cent	Contraction in area, per cent	Remarks
1	Normal	..	112	....	....	..
2	Annealed	40.0	58.0	18.0 %	35.0 %	Fibrous
3	Hardened	..	62.0	....	....	..
4	Hardened and Tempered	..	89.0	....	....	..

It will be observed that the ductility of the annealed specimen is very good, rendering the steel in a condition to withstand the great pressures due to the forces thrown upon it when cutting.

In preparing high-speed steel ready for use the process may be divided principally into three stages: forging, hardening and grinding. It is, of course, very desirable that high-speed steel should be capable of attaining its maximum efficiency and yet only require treatment of the simplest kind, so that an ordinarily skilled workman may easily deal with it, otherwise the preparation of tools becomes an expensive and costly matter, and materially reduces the advantages resulting from its use. Fortunately, the treatment of the rapid steel produced by the author's firm is of the simplest; simpler in fact than ordinary carbon steels or the old self-hardening steels, as great care had to be exercised in the heating of the latter steels, for if either were heated above a blood-red heat, say 1600° F., the danger of im-

pairing their efficiency by burning was considerable; whereas with the high-speed steel, heating may be carried to a much higher temperature, even up to melting point, it being practically impossible to injure it by burning. The steel may be raised to a yellow heat for forging, say 1850° F., at which temperature it is soft and easily worked into any desired form, the forging proceeding until the temperature lowers to a good red heat, say 1500° F., when work on it should cease and the steel be reheated.

In heating a bar of high-speed steel preparatory to forging (which heating is best done in a clear coke fire) it is essential that the bar be heated thoroughly and uniformly, so as to insure that the heat has penetrated to the center of the bar, for if the bar be not uniformly heated, leaving the center comparatively cold and stiff, whilst the outside is hot, the steel will not draw or spread out equally, and cracking will probably result. A wise rule in heating is to "hasten slowly."

It is not advisable to break pieces from the bar whilst cold, the effect of so doing tending to induce fine end cracks to develop which ultimately may extend and give trouble, but the pieces should be cut off whilst the bar is hot, then be reheated as before and forged to the shape required, after which the tool should be laid in a dry place until cold.

The temperature for hardening high-speed steel varies somewhat according to the class of tool being dealt with.

When hardening turning, planing or slotting tools, and others of similar class, the point or nose of tool only should be gradually raised to a white melting heat, though not necessarily melted, but even should the point of the tool become to a more or less extent fused or melted no harm is done. The tool should then be immediately placed in an air blast and cooled down, after which it only requires grinding and is then ready for use.

Another method which may be described of preparing the tools is as follows:

Forge the tools as before, and when quite cold grind to shape on a *dry* stone or *dry* emery wheel, an operation which may be done with the tool fixed in a rest and fed against the stone or emery wheel by a screw, no harm resulting from any heat developed at this stage. The tool then requires heating to a white heat, but just short of melting, and afterwards completely

cooling in the air blast. This method of first roughly grinding to shape also lends itself to cooling the tools in oil, which is specially efficient where the retention of a sharp edge is a desideratum, as in finishing tools, capstan and automatic lathe tools, brass-workers' tools, etc.

In hardening where oil cooling is used, the tools should be first raised to a white heat, but without melting, and then cooled down either by air blast or in the open to a bright red heat, say 1700° F., when they should be instantly plunged into a bath of rape or whale oil, or a mixture of both.

Referring to the question of grinding tools, nothing has yet been found so good for high-speed steels as the wet sandstone, and the tools ground thereon by hand pressure, but where it is desired to use emery wheels it is better to roughly grind the tools to shape on a dry emery wheel or dry stone *before* hardening. By so doing the tools require but little grinding after hardening, and only slight frictional heating occurs, but not sufficient to draw the temper in any way, and thus their cutting efficiency is not impaired. When the tools are ground on a wet emery wheel and undue pressure is applied, the heat generated by the great friction between the tool and the emery wheel causes the steel to become hot, and water playing on the steel whilst in this heated condition tends to produce cracking.

With regard to the hardening and tempering of specially formed tools of high-speed steel, such as milling and gear cutters, twist drills, taps, screwing dies, reamers, and other tools that do not permit of being ground to shape after hardening, and where any melting or fusing of the cutting edges must be prevented, the method of hardening is as follows:

A specially arranged muffle furnace heated either by gas or oil is employed, and consists of two chambers lined with fireclay, the gas and air entering through a series of burners at the back of the furnace, and so under control that a temperature up to 2200° F. may be steadily maintained in the lower chamber, whilst the upper chamber is kept at a much lower temperature.

Before placing the cutters in the furnace it is advisable to fill up the hole and keyways with common fireclay to protect them.

The mode of procedure is now as follows:

The cutters are first placed upon the top of the furnace until they are warmed through, after which they are placed in the

upper chamber and thoroughly and uniformly heated to a temperature of about 1500° F., or, say, a medium red heat, when they are transferred into the lower chamber and allowed to remain therein until the cutter attains the same heat as the furnace itself, viz., about 2200° F., and the cutting edges become a bright yellow heat, having an appearance of a glazed or greasy surface. The cutter should then be withdrawn whilst the edges are sharp and uninjured, and revolved before an air blast until the red heat has passed away, and then whilst the cutter is still warm — that is, just permitting of its being handled — it should be plunged into a bath of tallow at about 200° F., and the temper-

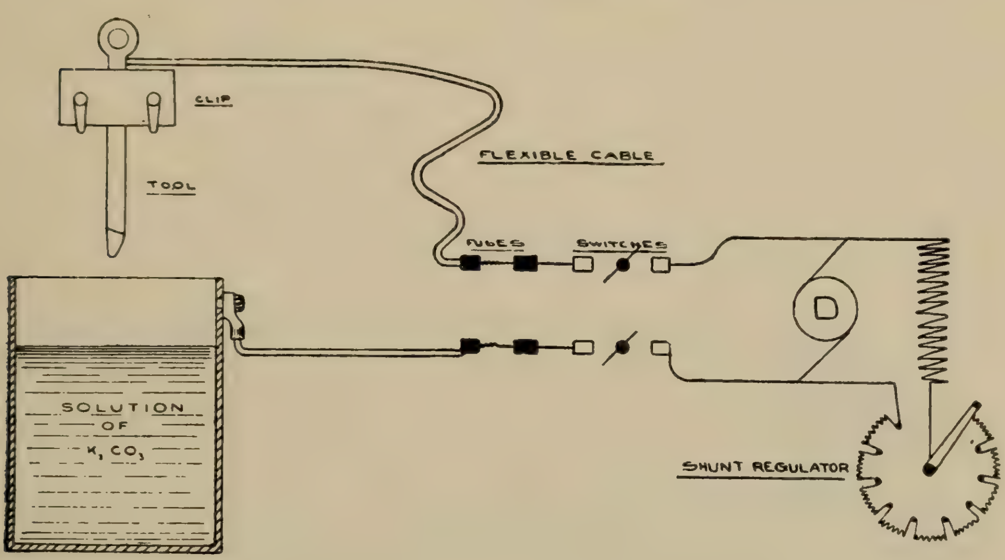

FIG. 1

ature of the tallow bath then raised to about 520° F., on the attainment of which the cutter should be immediately withdrawn and plunged in cold oil.

Of course there are various other ways of tempering, a good method being by means of a specially arranged gas-and-air stove into which the articles to be tempered are placed, and the stove then heated up to a temperature of from 500° F. to 600° F., when the gas is shut off and the furnace with its contents allowed to slowly cool down.

Another method of heating tools is by electrical means, and by which very regular and rapid heating is obtained; and where electric current is available, the system of electric heating

is quick, reliable and economical, and a brief description of this kind of heating may be of interest.

One method adopted of electrically heating the points of tools and the arrangement of apparatus is shown in Fig. 1. It consists of a cast-iron tank, of suitable dimensions, containing a strong solution of potassium carbonate together with a dynamo,

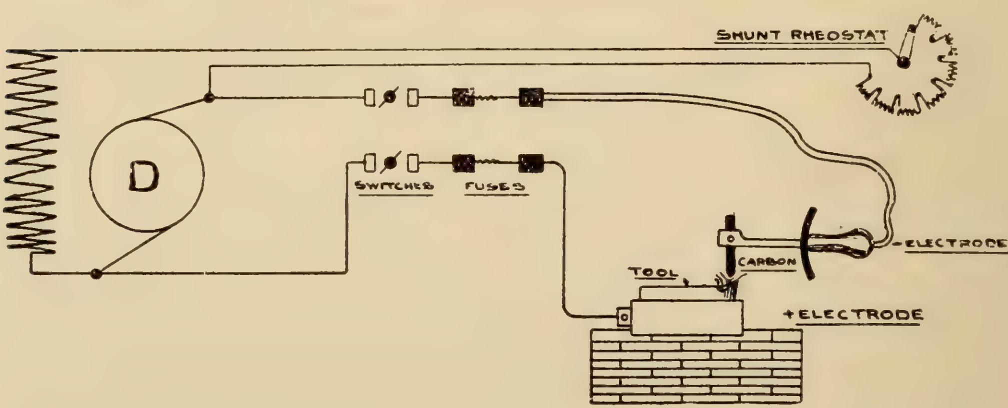

FIG. 2. Apparatus for Hardening High-Speed Tools by Means of an Electric Arc.

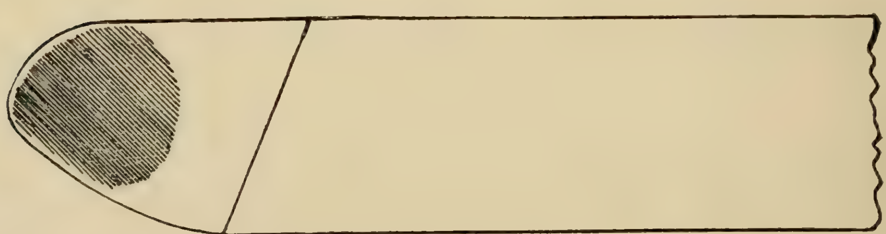

FIG. 2a. The Shaded Portion shows the area of Electrical Contact. The Negative Electrode should be kept moving over this Surface without approaching too near the Cutting Edge of the Tool.

the positive cable from which is connected to the metal clip holding the tool to be heated, whilst the negative cable is connected direct on the tank. The tool to be hardened is held in a suitable clip to insure good contact. Proceeding to harden the tool the action is as follows:

The current is first switched on, and then the tool is gently lowered into the solution to such a depth as is required to harden it. The act of dipping the tool into the alkaline solution completes the electric circuit and at once sets up intense heat on the immersed part. When it is seen that the tool is sufficiently heated the current is instantly switched off, and the solution then

serves to rapidly chill and harden the point of the tool, so that no air blast is necessary.

Another method of heating the point of tools is by means of the electric arc, the heating effect of which is also very rapid in its action. The general arrangement and form of the apparatus here employed being as illustrated in Fig. 2.

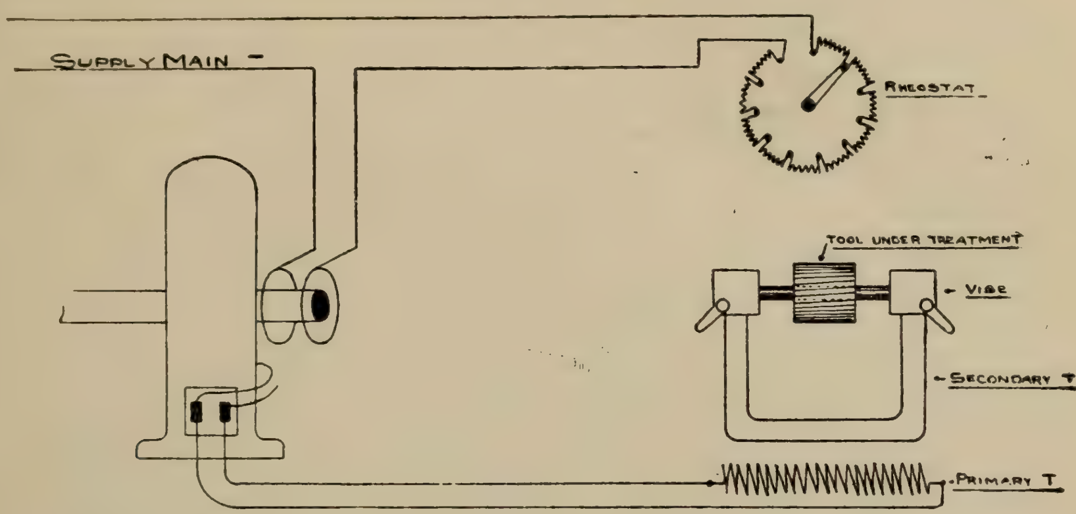

FIG. 3. Apparatus for Tempering Milling Cutters, etc., Electrically

The tool under treatment and the positive electrode are placed on a bed of non-conducting and non-combustible material and the arc started gradually at a low voltage and steadily increased as required, by controlling the shunt rheostat, care being taken not to obtain too great a heat and so fuse the end of the tool. The source of power in this case is a motor generator consisting of a continuous-current shunt-wound motor at 220 volts, coupled to a continuous-current shunt-wound dynamo at from 50 to 150 volts. Arcs from 10 to 1,000 amperes are then easily produced and simply and safely controlled by means of the shunt rheostat.

Tempering. — Electricity is also a very efficient and accurate means of tempering such forms of tools as milling, gear, hobbing and other similar cutters, also large hollow taps, hollow reamers, and all other hollow tools made of high-speed steel, where it is required to have the outside or cutting portion hard, and the interior soft and tenacious, so as to be in the best condition to

resist the great stresses put upon the tool by the resistance of the metal being cut, and which stresses tend to cause disruption of the cutter if the hardening extends too deep.

By means of the apparatus illustrated in Fig. 3, this tempering or softening of the interior can be perfectly and quickly effected, thus bringing the cutter into the best possible condition to perform rapid and heavy work.

Tempering of hollow cutters, etc., is sometimes carried out by the insertion of a heated rod within the cutter and so drawing the temper, but this is not entirely satisfactory or scientific, and is liable to induce cracking by too sudden heat application, and further because of the difficulty of maintaining the necessary heat and temperature required, and afterwards gradually lowering the heat until the proper degree of temper has been obtained. In electrical tempering these difficulties are overcome, as the rod is placed inside the cutter quite cold, and the electric current gradually and steadily heats up the rod to the correct temperature as long as is necessary, and the current can be gradually reduced until the articles operated on are cold again, and consequently the risk of cracking by too sudden expansion and contraction is reduced very greatly. The apparatus used is very simple, as will be seen by reference to the sketch. It consists of a continuous-current shunt-wound motor directly coupled to a single-phase alternating-current dynamo of the revolving field type, giving 100 amperes at 350 volts, 50 cycles per second, the exciting current being taken from the works supply main.

The power from the alternator is by means of a stepdown transformer, reduced to current at a pressure of 2 volts, the secondary coil of the transformer consisting of a single turn of copper of heavy cross-section, the extremities of which are attached to heavy copper bars carrying the connecting vices holding the mandrel upon which the cutter to be tempered is placed. The secondary induced current, therefore, passes through a single turn coil, through the copper bars and vices and mandrel.

Although the resistance of the complete circuit is very low, still, owing to the comparatively high specific resistance of the iron mandrel, the thermal effect of the current is used up in heating the mandrel, which gradually attains the required tem-

perature, slowly imparting its heat to the tool under treatment until the shade of the oxide on the tool satisfies the operator.

The method adopted to regulate the heat of the mandrel is by varying the excitation current of the alternator by means of the rheostat. An extremely fine variation and perfect heat control is easily possible by this arrangement.

Uses. — Having touched upon the development and thermal treatment of high-speed steel, it will now be opportune to refer to its practical use and to some of the most recent work done with it. It is sometimes contended that on the whole not much advantage or economy results from using high-speed steel, but it is easy to prove very greatly to the contrary, and the author proposes to give some figures and facts as to its use and advantage, not only by knowledge gained from results of his own firm, but also from information supplied by many important engineering establishments as to their present workshop practice, and for which he is indebted.

That great economy is effected is beyond all doubt, from whichever point of view the question is looked at; for it is not only rapidity of cutting that counts, but the output of machines is correspondingly increased, so that a greater production is obtained from a given installation than was possible when cutting at low speeds with the old tool steel, and the work is naturally produced at a correspondingly lower cost, and of course it follows from this that in laying down new plant and machines the introduction and use of high-speed steel would have considerable influence in reducing expenditure on capital account.

It has also been proved that high-speed cutting is economical from a mechanical standpoint, and that a given horse-power will remove a greater quantity of metal at a high speed than at a low speed, for although more power is naturally required to take off metal at a high than at a low speed (by reason of the increased work done) the increase of that power is by no means in proportion to the large extra amount of work done by the high-speed cutting, for the frictional and other losses do not increase in anything like the same ratio as a high-cutting speed is to a low-cutting speed. A brief example of this may be given in which the power absorbed in the lathe was accurately measured electrically.

Cutting on hard steel, with three-sixteenths inch depth of cut, one-sixteenth inch feed and speed of cutting 17 feet per

minute, a power of 5.16 horse-power was absorbed, and increasing the cutting speed to 42 feet per minute, the depth of cut and feed being the same, there was a saving in power of 19 per cent for the work being done.

Another experiment with depth of cut three-eighths inch and traverse one-sixteenth inch compared with one-sixteenth inch traverse and three-sixteenths inch depth of cut, showed a saving in power of as much as 28 per cent, and still proceeding with a view of increasing the weight of metal removed in a given time the feed was doubled (other conditions being the same), and a still further saving of power resulted. In a word, as in the majority of things, so it is with rapid cutting, the more quickly work can be produced the cheaper the cost of production will be.

Again, as regards economy there is not only a saving effected on the actual machine work, but since the advent of high-speed cutting it is now possible, in many instances, to produce finished articles from plain rolled bars, instead of following the old practice of first making expensive forgings and afterwards finishing them in the machine. By this practice not only is the entire cost of forging abolished, but the machining on the rolled bar can be carried out much quicker and cheaper in suitably arranged machines, quicker even than the machining of a forging can be done.

Many wonderful examples in proof of this can be given. Taking the two articles illustrated below: these were machined from plain rolled bars with high-speed steel in 45 minutes and 13 minutes respectively, as against $3\frac{3}{4}$ hours and $1\frac{3}{4}$ hours when made from forgings and using ordinary tool steel.

Another remarkable sample of the gain resulting from the use of high-speed cutting from rolled bars is illustrated in the case of securing bolts, made by the author's firm, for armor plates. Formerly where forgings were first made and then machined with ordinary self-hardening steel, a production of eight bolts per day of ten hours was usual. With the introduction of rapid-cutting steel, forty similar bolts from the rolled bar are now produced in the same time, thus giving an advantage of five to one in favor of quick cutting, and also in addition abolishing the cost of first rough forging the bolt to form; in fact, the cost of forging one bolt alone amounted to

more than the present cost of producing to required form twelve such bolts by high-speed machining. The cutting speed at which these bolts are turned is 160 feet per minute, the depth of cut and feed being respectively three-quarters inch and one

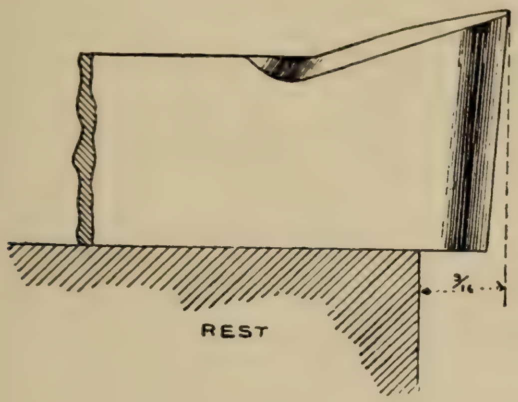

FIG. 5

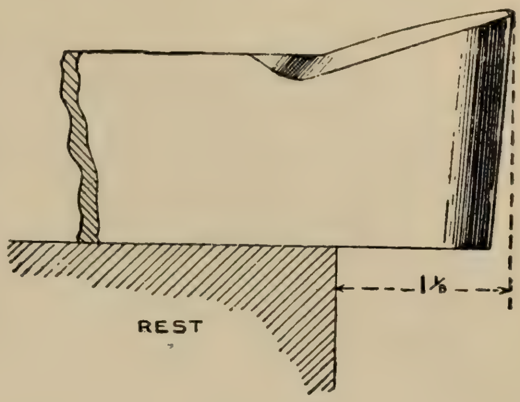

FIG. 4

thirty-second inch, the weight of metal removed from each bolt being 62 pounds, or 2,480 pounds in a day of ten hours, the tool being only ground once during such period of work, and from such an example as this it will be at once apparent what an enormous saving in plant and costs results. On the same principle the sleeves for these bolts are produced from bars, 60 being made in one day of ten hours, this being even a greater saving on the old system than the bolt example shows.

The lathe on which this work is done is a 12-inch lathe of special design and strength for rapid and heavy cutting, and has a link driving belt of 7½ inches wide, running at a very high velocity and driven by its own motor, so that the power absorbed can always be observed whether the lathe is running idle or cutting.

Equally remarkable results are obtained by operating on stock bars with high-speed milling cutters, and one example, amongst many, may be cited: Hexagon nuts for 3⅜ inch diameter bolts are made from rolled bars, the cutting speed of milling being 150 feet per minute, giving a production of 90 nuts per day, against 30 formerly. More than 90 nuts could have been produced had the machine been more powerful.

A further economy of the great saving resulting from the

use of high-speed steel was recently supplied to the author by one of the largest manufacturers of textile machinery in Lancashire, and they wrote as follows:

"Our results up to the present time, without being phenomenal, have demonstrated the fact that there are great possibilities for effecting considerable saving by its use, and, as examples, would mention the following:

"In the drilling of cast-iron rails, we have been able to increase the speed from four to eight times, and in one case of milling [cast-iron] we have, by building a special milling machine, and the use of the new material, increased the output six times as compared with that obtained under the older conditions.

"In another case we have been able to obtain 20 per cent reduction in the piece-work price of the turning of some small steel articles, and we have no doubt that there are other instances, especially where we are prepared to build stronger machines, where similar and even greater savings can be effected."

One phase of milling in which cutters made from high-speed steel will play an even more important part than at the present time will be that of gear and similar cutting, it now being possible to make formed backed-off cutters of high-speed steel for all purposes, and the results obtained from the use of them prove beyond all doubt that very great advantage is to be gained from their application and use.

Again, rapid cutting with planing tools has also developed extensively, the old cutting speeds of 15 to 25 feet per minute being now replaced by those of 50 to 60 feet per minute, and in some cases even as high as 80 feet per minute, and for the same reasons, as already described in lathe turning, the power absorbed does not increase in anything like the same proportion to the extra amount of work done, so that the wear and tear on the machine is not materially increased.

It was for some time not thought possible to plane at such high speeds on acount of the tools coming into contact suddenly with the job and running risks of snapping off through shock, but where high-speed steel of proper quality is used this difficulty is overcome, and a good example or two of rapid planing may be quoted. Using a 7-foot planing machine with two tools operating on forged steel of medium quality, the cutting speed, depth of cut and feed of each tool is respectively 54 feet, one-fourth inch, and one-eighth inch, the speed of reverse being 160 feet per minute.

Another striking example of high-speed planing on a large cast-iron turbine body was: Cutting speed 36 feet per minute, depth of cut 1.25 inches, and feed 7 cuts per inch, the tool cutting for 10 hours without necessitating grinding. Two tools were cutting, each taking a cut as described, the size of the planer being 14 feet by 14 feet by 30 feet.

The question of cutting angles for tools is an important one, and the author would advise all interested to peruse the paper written by Professor Nicolson of Manchester, and read before the Institution of Mechanical Engineers at Chicago this year, and in which he states that the best cutting angle as deduced from the results of experiments is 75° for steel and 80° for cast iron. Of course these angles may with advantage be modified according to circumstances and the nature of any particular class of work.

Objections have been made against high-speed steel on the ground of its being brittle; but this is not the case where the steel has been properly annealed and the hardening confined to the cutting area, and sufficient support given to the tools when fixed in the machine.

An example of the great pressure-resisting powers of high-speed steel may be given.

When cutting forged steel of about 30 tons per square inch tensile strength and offering a resistance to cutting of about 100 tons per square inch, a tool of $1\frac{1}{4}$ square inch section was used, taking a cut of seven-eighths inch in depth by one-fourth inch feed per revolution, equivalent to an area of metal under cut of 0.21875 square inch, the cutting speed being 90 feet per minute, and removing $68\frac{3}{4}$ pounds of metal per minute, or the huge weight of 4,010 pounds per hour. The tool in this instance was projecting a distance of $1\frac{1}{8}$ inches beyond the rest (see Fig. 4), and a calculation shows the stress on the tool to be as high as 78.5 tons per square inch. In another case, cutting forged steel of 35 tons tensile strength and offering a resistance to cutting of 115 tons per square inch, a $1\frac{1}{4}$ inch square tool being used, the diameter of forging was reduced by 1 inch, equal to one-half inch depth of cut, whilst the tool advanced three-eighths inch every revolution, the cutting speed being 25 feet per minute and removing $14\frac{1}{4}$ pounds of metal per minute. With the point of the tool projecting three-fourths inch beyond

the rest, the tool successfully withstood a stress of 51.6 tons per square inch. (See Fig. 5.)

Although in actual practice tools of much greater section would be used, the results clearly show that, if proper care be taken, tools of high-speed steel are quite capable of withstanding any pressure likely to be met in ordinary workshop practice.

A most important point to observe when taking heavy cuts is that of having the tools quite flat on the bottom side and supported as near as possible up to the extreme edge, as by so doing the pressures tending to break the tool are very considerably reduced. For example, the position of the tool as placed in the rest shown in Fig. 4 would cause a stress of something like 78.5 tons per square inch to be thrown on it, whereas when the overhang is reduced to one half of the original distance, equal to nine-sixteenths inch, the stress is lowered to 14.27 tons per square inch, a reduction of 80 per cent.

Perhaps one of the most unlooked-for developments in the use of high-speed steel has been the manufacture from it of twist drills, and it would be safe to say that in no other sphere has the new steel justified itself to a greater extent than in the operations of drilling and boring, as its powers in that respect have revolutionized completely modern workshop practice. It is now possible in many cases to drill holes through stacks of thin steel plates as quickly and economically as by punching them, thus avoiding the consequent liability to distress the material due to punching action.

The plates of torpedo and other boats, which are comparatively thin and of high tensile strength, can now be drilled in stacks with such facility that it is no longer necessary to punch the holes, whilst in many articles where it was formerly the practice to core in the holes, as, for example, in cylinder and other covers, or pipe flanges, etc., it is now cheaper and quicker to use high-speed steel and drill the holes out of the solid. Many examples might be adduced in support of these statements, but reference is made to a few striking instances.

A short time back the author received a letter from a large firm of structural engineers in Glasgow giving some remarkable drilling results with high-speed drills, and the following extract may be quoted:

"Drilling mild steel 2½ inches thickness made up of five three-eighths inch plates and one five-eighths inch angle iron, a fifteen-sixteenths inch diameter twist drill made of high-speed steel, and running at 275 revolutions per minute, with a feed of 75 cuts per inch of penetration, drilled 7,924 holes without requiring regrinding, each hole being drilled in 42 seconds."

As a comparison of the superiority of high-speed over ordinary drills, an instructive result was obtained when drilling forged steel gun-cradles of 5 inches thickness, and which steel is of a very tough nature. An ordinary twist drill was first tried and failed after drilling 8 holes, the end being completely fused, but a high-speed drill afterwards drilled 124 holes without suffering any injury whatever. The drills were 2 inches diameter, running at 80 revolutions per minute, and each hole was drilled in six minutes, this being the full power of the machine.

A further illustration of the economy resulting from the use of high-speed twist drills may be gathered from the fact that the author's firm in several instances reduced the cost of drilling per 100 holes by over 60 per cent without even altering the machines in any way, except by speeding them up.

On cast iron equally good results are obtained. Opening out cored holes in cast-iron girders, from five-eighths inch to fifteen-sixteenths inch diameter, the high-speed drills do four and a half times as much work as the drills previously used, in addition to lasting considerably longer without grinding, whilst in another operation where the holes are drilled out of the solid the difference in production is eight times in favor of the high-speed drill.

Equally satisfactory results are obtained from flat drills and other forms of boring tools made of high-speed steel for use in boring large holes out of solid bars, shafts, forgings, etc., the author's firm daily using drills of this type up to 12 inches diameter and boring holes up to 50 feet long.

Other miscellaneous uses to which high-speed steel may be applied include taps, screwing dies, reamers, hot punches, circular saws, both solid and with teeth inserted in mild steel bodies, marble drilling, marble planing, rock drills, etc., also in the case of articles whose surfaces are subject to hard wear, such as lathe centers, tube expanding tools, etc.

Finishing. — A considerable amount of doubt has been thrown from time to time on the inability to take finishing cuts

with high-speed steel, and in the early stages of its development this contention was to a large extent justified, but experience and practice have brought the steel into line and rendered it possible to obtain an excellent finish at high speeds with tools suitably formed and properly arranged in the machines. Some very good examples of finished bright work at high speeds have been made mostly in semi-automatic machines, high-speed steel being used and *one* cut only taken, the surface finish being most excellent.

These samples, along with many others illustrate the finishing powers of high-speed steel when used in machines suitably adapted, and they have been turned from the rolled bar with *one* cut only, being guaranteed accurate in diameter to 0.002 of an inch, whilst the excellence of surface finish will compare with the best obtainable by the old system of cutting, finishing and polishing.

This finishing quality of high-speed steel is especially advantageous for tools used in automatic and capstan lathes, because it enables the work to be produced so very much more rapidly; and also, on account of the great resistance of the steel to wearing action, greater accuracy is insured.

As regards the quality of retaining a sharp edge, high-speed steel makes excellent razors, and will long retain without sharpening an extremely keen cutting edge. The author may add that it is thus now possible to those whose time is precious to indulge even in "high-speed shaving."

The author hopes that the few facts he has given as to the use and development of high-speed steel may indicate some of its uses and progress, but he can scarcely refrain from remarking that many are saying, and rightly so, "Yes! these results are very remarkable; but what of the machines to perform such prodigious work?" and this leads him to speak before concluding as to how one important development often leads up to another of even greater magnitude, and that is in this case the complete revolution in the design of machine tools to cope with the extraordinary increased cutting powers of the latest rapid cutting steels.

It is impossible that the design of machine tools can remain on the old lines, since the difference between them and the cutting powers of the steel is so abnormal, and a sphere of im-

mense area for the redesigning of machine tools is opened out to the ingenuity of the world's engineers.

That much has been already done is admitted, but the work is naturally of such a nature that only time and experience will accomplish, gradually enabling as nearly as possible the relative powers of the steel and machines to be equated.

In the machine tool department of the author's firm, this branch of the subject of remodeling their tools has received the closest attention, and a type of their modern 18-inch center lathe for high-speed cutting may be mentioned. It is capable of exerting 65 horse-power equivalent to a belt width of 12 inches, and with the aid of a variable speed motor a range of cutting speeds from 16 to 400 feet per minute is possible, this comparing with an old-type 18-inch lathe having a belt of 4-inch width, and capable of exerting only about 12 horse-power.

In a similar way the old types of planing, milling, drilling machines, etc., are all more or less obsolete, and new designs are already constructed to cope with work at speeds and feeds described in this paper.

It is indeed a pleasure to see the new type of machine tool operating with high-speed steel, and treating the work it has to turn out in such a businesslike way, throwing off shavings from steel and iron as one usually sees in turning wood, and imparting a life and energy to the whole establishment in remarkable contrast to the sleepy rate at which metals used to be turned and machined for so many years past, thus exerting an influence on everybody therein to get "a hustle" on that is positively exhilarating in its effects.

The chemists and metallurgists, with the skill they have brought to bear in assimilating the metals provided by nature to make so wonderful a product as this high-speed steel, have set a formidable task to the mechanical world; but it is satisfactory to observe that in most quarters, engineers, although for the time being in a secondary position, are roused to exercising their fullest energies in getting level. This competition can only be considered as a healthy sign, since it will give further impetus to the steel maker, and remind him to continue to fathom more and more the mysteries and powers of this steel.

In concluding this paper the author would add, it cannot be denied that the question of high-speed steel is one of vast im-

portance to all manufacturing countries, for if they are to hold their position in the world's competition they will be compelled to study the use and advantages to be derived from its adoption, and, in addition, to bring up their machinery into the most modern and efficient form for obtaining the utmost producing capacities.

The powers of the cutting steel and the machine should be as nearly reciprocal as possible, for, given those conditions, manufacturers place themselves in the most favorable position for the rapid and economical turn-out of their products, and for best meeting their rivals in the open field of competition; and lastly, notwithstanding the wonderful results obtained with the new cutting steel, and developed comparatively so rapidly, nothing approaching finality must be admitted by the steel maker, but incessant diligence, experiment and research to discover still more the best combinations of nature's metals, should be his constant aim, and in the doing of which not only is there much pleasure derivable to himself, but in addition there is the benefit it is possible to render to the whole world.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

THE **Electro-Metallurgy of Iron.** L. Francois; and L. Tissier. — The application of electricity to the metallurgy of iron is certainly one of the most interesting problems confronting the electro-chemist. The original investigations in this line were made about sixty years ago.

Siemens was the first to describe, in 1879, several electric melting furnaces employing the arc directly or indirectly. About 1893 other trials were undertaken by Laval, Taussig, Urbanitsky and Fellner, but no results were obtained. It was only in 1900 that Heroult, and then Stassano, after long investigations, succeeded in industrially obtaining iron electrically. This year electro-metallurgy may be said to have entered the industrial domain. It is calculated that in Europe there are at present seven installations, at least the same number in America, and some others in Chili.

Having thus introduced their subject, the authors described the processes by which iron or steel or other alloy can be prepared. See accompanying illustrations.

The furnace employed in the Gin and Leleux process is formed of refractory masonry which envelopes a movable metal crucible forming the roasting chamber and constituting the cathode. This method can only be applied in the treatment of raw metal.

The Heroult process utilizes the principle of Laval. The

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furnace consists essentially of a crucible in which the electrodes dip; there are two outlet holes at different levels, the lower one serving for the outlet of the metal, and the other for the evacuation of the slag.

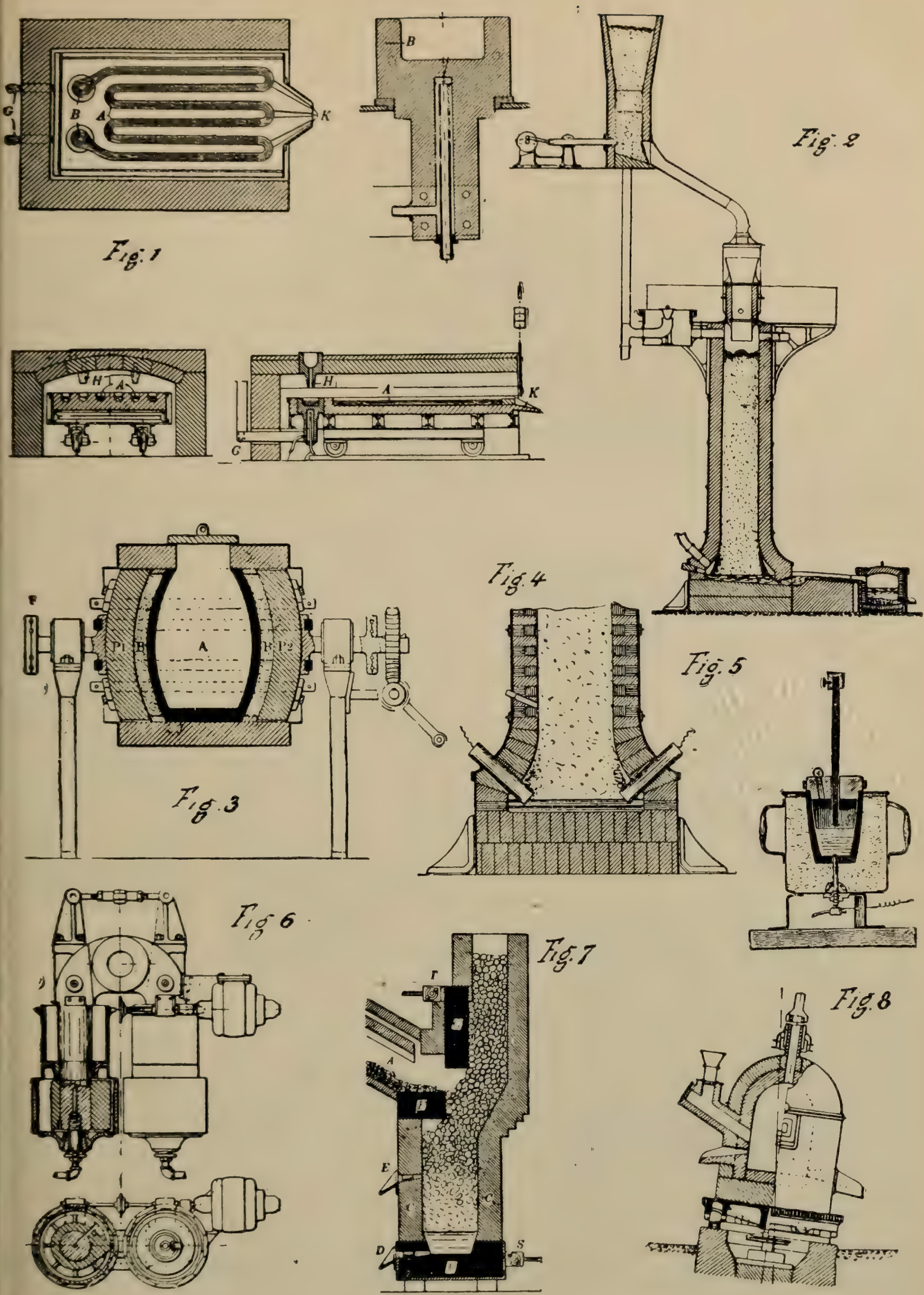
Among the furnaces based on this process, the Bessemer has given excellent results. It gives steel very much resembling crucible steel. By the Stassano process, steel of a desired quality and composition can be obtained. Italian ores of average quality are employed. The new type of Stassano furnace is arranged to revolve around a slightly inclined axis on a horizontal plane, so that by rotation a puddling of the mass is produced. The cost of manufacture is not very high.

The Keller system consists of two furnaces arranged in series, one for preparing the raw metal, the other for refining. The former resembles an ordinary blast furnace. The roasting chamber is slightly inclined, and a little above it are two openings for the flow of the molten metal and the slag. Occasionally the bottom is opened, so that the metal may flow into the second furnace, where the impurities and the slag become completely separated from the metal mass. This process is very applicable in countries possessing waterfalls and where fuel is scarce.

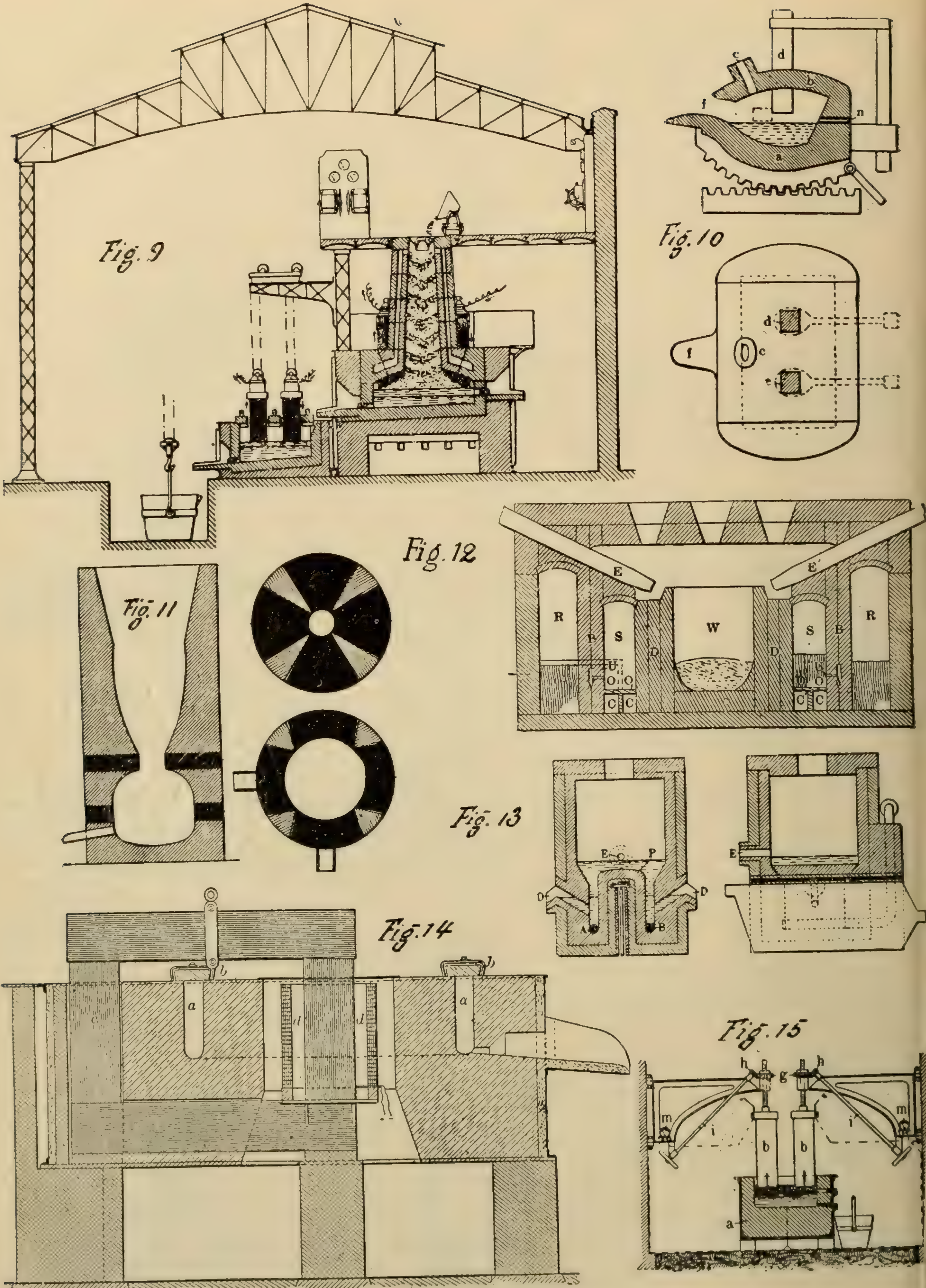
The Neuburger-Minet furnace is arranged so as to utilize separately or simultaneously three sources of heat, — blast furnace gases, rich or poor gases coming from gasworks and the electric current in the form of an arc. By this process iron, steel and alloys of chrome, silicon, tungsten and vanadium can be obtained.

The Conley process, employed by the Electric Furnace Company, America, gives steel of an excellent quality, rivaling the finest crucible steel. Two crowns composed of graphite and clay constitute the electrodes.

The Harmet process is employed in the St. Etienne Forge and Steel Works, and necessitates three furnaces, one for the fusion of the ores, a second for the reduction and a third for the refining of the raw metal obtained. The three furnaces are electrically operated, but the first two can be replaced by an ordinary blast furnace if the economic conditions of the district render it necessary. According to the inventor, the power necessary for producing one ton of steel is 3,600 horse-power hours.



(1) The Gin Electrical Furnace; (2) the Harmet; (3) the Girod; (4) the Harmet; (5) the Siemens; (6) the Ruthenburg; (7) the Heroult; (8) the Stassano.



(9) The Keller Furnace; (10) the Heroult; (11) the Conley; (12) the Minet; (13) the de Laval; (14) the Kjellin; (15) Furnace working on the de Laval principle.

The authors next describe briefly the Girod, Gysinge and Ruthenburg processes, terminating the technical part of their paper in describing an electric furnace which differs very much from these previously mentioned. One of the electrodes consists of the crucible itself, the other being placed vertically on the upper part of the apparatus.

Passing to the economic part of their paper, they cite the opinions of Messrs. Simpson, Goldschmidt and Gin, very competent specialists.

According to Mr. Simpson, the following are the advantages of the electric furnace:

1. Production of very compact and homogeneous steel. 2. A minimum amount of work necessary and the possibility of varying the work and of producing iron, steel or fixed alloys. 3. Facility of increasing, diminishing, stopping or restarting the process of manufacture without any injury to the furnace, as is the case with blast furnaces. 4. A limited number of workmen. 5. The relatively small price of the installation, partly counterbalancing the expense entering into the production of electric power.

Finally, according to Mr. Gin, the Martin furnace can be replaced by an electric apparatus, so that the iron metallurgical industry will be endowed with a complete equipment:

1. A blast furnace for the production of wrought steel.
2. The Bessemer, for the production of ordinary steel.
3. An electric purifier for obtaining fine steel. "Engineering Press Index Review," September, 1904. **No. 261. B.**

The Production of Iron and Steel by the Electric Furnace. W. McClure. "The Engineering Review," November, 1904. 3,500 w., 13 illustrations. — The author describes the various methods and furnaces used for the electrical production of iron and steel, including the following processes: Stassano, Keller, Heroult, Kjellin, Gin, Harmet, Girod and Conley. Following Dr. Stansfield's classification he divides the processes as follows:

(1) Treatment of molten pig iron as it comes direct from the blast furnace for the purpose of refining and converting it into steel of certain grades. This may be called the electro-refining of steel.

(2) Treatment of cold pig iron, or a mixture of pig and suitable scrap, to produce iron and steel.
(3) Production of various ferro-alloys by either of the following methods:
  (*a*) Starting with a mixture of iron ores and ores of the metal to be alloyed; or
  (*b*) Starting with a mixture of pig iron and minerals to be reduced and alloy therewith.

The author concludes with the following words:

As regards the prospects of the electric furnace in the immediate future, it is not probable, except under very special conditions, that it will replace the blast furnace or the converter or open-hearth in the production of pig iron and ordinary steel respectively; but in the case of tool steel it is certain to find an important application by the utilization of waste gases for the generation of the necessary current.

As, however, experience in electric smelting accumulates and the absorption of electric energy has, by a more suitable design of furnace, been reduced to a minimum, it may be reasonable to expect that some of the present methods may be displaced in localities where necessary facilities exist for iron and steel production. **No. 262. B.**

The Electro-Metallurgy of Iron and Iron Alloys. N. Newmann. "Stahl und Eisen," June 15, July 1 and 15, August 1 and 15, 1904. Illustrated. — The subject is treated at length under the following headings: (1) The process and apparatus employed; (2) the composition of the different products obtained; (3) the dynamic expense and thermic efficiency; (4) cost and (5) the electrical manufacture of iron and steel and the processes usually employed in metallurgy. **No. 263. Each C.**

The Manufacture of Ferro-Alloys in the Electric Furnace. George P. Scholl. "Electro-Chemical Industry," September, October and November, 1904. 7,000 w., illustrated. — The author describes the manufacture in the electric furnace of all ferro-alloys which are at present produced on an industrial scale, including ferro-silicon, ferro-chromium, ferro-manganese, ferro-tungsten, ferro-vanadium, ferro-molybdenum and ferro-titanium. **No. 264. Each B.**

Tin Steels (Les Aciers à l'Etain). L. Guillet. "Revue de Métallurgie," September, 1904. 1,000 w., 5 photomicrographs. — These steels, according to the results of M. Guillet's work, do not possess much industrial value; they present, however, some interesting features worthy of note. The contents of carbon and tin in the alloys prepared areas follows:

First Series		Second Series	
Carbon %	Tin %	Carbon %	Tin %
0.204	1.79	0.760	2.05
0.152	5.02	0.665	4.80
0.100	9.98	0.767	9.75

With the exception of the first member of the second series, none of the steels would forge, a feature attributed to two causes: (1) the high mineralogical hardness and (2) the extreme fragility of the steels. As a result of this failure to forge no mechanical tests are given; emphasis is, however, laid on the fragility and hardness. The micrographic features of the alloys are not very dissimilar to those of ordinary iron carbon steels, and the first series up to 5 per cent tin present normal ferrite and pearlite. Exceeding 5 per cent tin, the pearlite areas appear to be surrounded with white patches, which sometimes take a needle form. The second series presents similar feaures, and from the microscopical examination it is concluded that in tin steels containing less than 10 per cent tin all the carbon is in the state of carbide of iron, whilst the tin is held in solution in the iron. Experiments on quenching and annealing have, as far as structure is concerned, yielded similar results to those obtained from carbon steels. Tin does not aid the precipitation of free carbon, for annealing at 1200° C. for ten hours has in no case produced graphite. Cementation experiments have shown that the presence of tin considerably retards the process of cementation. Finally, M. Guillet, from his many experiments on cementation with various special steels, reaches the following conclusion: "Elements which dissolve in iron diminish the speed of cementation, whilst elements which form carbides increase it." From the tabulated results we gather that the presence of nickel, titanium, silicon or aluminum diminish the speed of carbon penetration, whilst manganese, tungsten,

chromium and molybdenum increase it. "The Engineering Review," November, 1904. **No. 265. B.**

Titanium Steels (Les Aciers au Titane). L. Guillet. "Revue de Métallurgie," September, 1904. 1,000 w., 3 photomicrographs. — Much has been written on titanium in cast iron and steel, but comparatively few definite properties induced by the presence of this element have been given. We therefore turn with anticipation to a research of M. L. Guillet's on titanium steels, contained in a recent issue of the "Revue de Métallurgie." In endeavoring to follow his usual plan of investigation, some difficulty was encountered in making the first series, owing to the high content of carbon contained in the ferro-titanium used. As a result, the highest content of titanium in the low carbon series is found at 3 per cent. Of the second series, containing 0.7 per cent carbon, steels have been examined containing up to 10 per cent titanium. In attempting to exceed this latter content, an insurmountable difficulty is met with in fusing the alloys — at any rate, as far as ordinary steel-works crucible furnaces are concerned. Tensile tests of the steels present no unusual features, the mild series containing from 0.415 per cent to 2.57 per cent titanium, all yielding very similar values. Similar tests of the second series, which contains about 0.7 per cent carbon, and titanium varying from 0.325 per cent to 8.710 per cent, also show little variation; if anything, the highest content of titanium yields the greatest breaking load and limit of elasticity, but the increase is not specially marked. The metallographic features of the alloys also show no dissimilarity from ordinary carbon steels. Titanium up to 7 per cent does not modify the structure; it is apparently dissolved in the iron, a conclusion supported by the results of quenching and annealing experiments. The results of mechanical tests and micrographic examination show titanium to have no sensible influence on the properties of carbon steels, and that titanium steels present comparatively little industrial interest. "The Engineering Review," November, 1904. **No. 266. B.**

The Chemical Analysis of High-Speed Steels and Alloys. Fred Ibbotson. "Technics," October and November, 1904.

7,500 w. — A fully descriptive article on the chemical analysis of high-speed steels, including the determination of carbon, tungsten, silicon, molybdenum, chromium and of some minor constituents. **No. 267. Each B.**

A Typical "Independent" Steel Plant, as illustrating the Chance of Smaller Producer. Victor Beutner. "The Iron Trade Review," October 27, 1904. 4,500 w., 11 illustrations. — A description of the United States Steel Company's works at Canton, Ohio. **No. 268. A.**

The Ore Unloading Plant of the American Steel and Wire Company. "The Iron Trade Review," November 3, 1904. 500 w., illustrated. **No. 269. A.**

Gas Producer for Bituminous Coal. Constructed by Messrs. W. F. Mason, Limited, Manchester, England. "Engineering," October 21, 1904. 500 w., illustrated. **No. 270. B.**

The Introduction of High-Speed Steel into the Factory. W. B. "The Iron Age," November 10, 1904. 1,200 w. **No. 271. A.**

Hadfield's Crushing Machinery. "The Iron and Coal Trades Review," October 28, 1904. 1,500 w., illustrated. — Describes the "Heclon" and other crushers made of Hadfield's manganese steel, as well as other crushing machinery. **No. 272. B.**

Inclined Cable Lifts for Blast Furnaces (Gichtseilbahnen). Rudolph Brennecke. "Stahl und Eisen," October 1, 1904. 2,500 w., illustrated. **No. 273. C.**

The Influence of Carbon, Silicon, Manganese, Sulphur and Phosphorus upon the Formation of Temper Carbon in Iron (Der Einfluss von Kohlenstoff, Silizium, Mangan, Schwefel, und Phosphor auf die Bildung der Temperkohle in Eisen). F. Wirst and P. Schlosser. "Stahl und Eisen," October 1, 1904. 2,000 w. **No. 274. C.**

Industrial Uses of Thermite. U. S. Cons. Repts. July, 1904. 1,400 w. **No. 275.**

Notes on the Tempering of Steel (Etudes sur la Trempe de l'Acier). Henry le Chatelier. " Revue de Métallurgie," September, 1904. 8,000 w. **No. 276. E.**

The Baraboo Iron Ore. N. H. Winchell. " American Geologist," October, 1904. 4,500 w. **No. 277.**

The Influence of Heat upon Mild Steel Plates (Versuche uber die Festigkeitseigenschaften von Flusseisenblechen bei Gewhönlicher und Höherer Temperatures). C. Bach. " Zeitschr. d. Ver Deutscher Ing.," August 27, September 3, 1904. 7,000 w. **No. 278. Each C.**

Slabbing Mill of the Lackawanna Steel Company. " The Iron Trade Review," October 27, 1904. 1,000 w., illustrated. **No. 279. A.**

Electric Smelting of Iron and Steel. J. H. Stansbie. " The Iron and Coal Trades Review, November 4, 1904. Abstract of a paper before the Staffordshire Iron and Steel Institute. — The author describes some of the most successful types of furnaces which have been used for the electrical production of steel. **No. 280. B.**

Pig Iron in Its Commercial Aspects. F. M. Thomas. " The Iron and Coal Trades Review," September 23, 1904. 4,500 w. — Abstract of a lecture delivered before the Birmingham Metallurgical Society. The author describes the different varieties of pig iron and their uses, with special reference to English practice. **No. 281. B.**

The Analysing and Grading of Iron Ores. Edward A. Separk. " Engineering News," September 1, 1904. — Abstract of a paper prepared for the annual meeting of the Lake Superior Mining Institute, August 16, 1904. **No. 282. B.**

METALLURGICAL NOTES AND COMMENTS

William E. Corey. — William E. Corey was born some thirty-eight years ago, the son of a retired coal merchant of Braddock, Pa. At the age of sixteen he entered the laboratory of the Edgar Thomson Steel Works, where his close attention and application to his work attracted to him the attention of his superiors, and he was soon transferred to a more responsible position in the order department of the Homestead Steel Works. In a comparatively short time he was made superintendent of the plate mills and open-hearth department at these works. It was not long after his appointment to this position that the manufacture of armor plate for the government was begun at Homestead. A strong, capable man being required for the superintendency of this department, Mr. Corey was chosen. How well he filled the requirements of this position is well known. The armor plate department under his management became world famous, its success being greatly due to the introduction by him of a new and valuable reforging process. Mr. Charles M. Schwab, at that time general superintendent of the Homestead Steel Works, being called to the presidency of the Carnegie Steel Company, Mr. Corey succeeded him as general superintendent at Homestead, and at the same time was admitted to partnership in the Carnegie Steel Company. To the responsibilities of the management of the Homestead Steel Works, no small task in itself, was soon afterward added the superintendency of the Carrie Furnaces and also of the Howard Axle Works, these combined forming at that time the largest group of steel plants under one head in the world. So successful was his management that when Mr. Schwab was called to higher responsibilities, as president of the Carnegie Steel Company, Mr. Corey was his logical successor, and again on the retirement of Mr. Schwab from the presidency of the United States Steel Corporation, Mr. Corey was elected to the presidency of this great company.

So successful a career should be an incentive to young metallurgists and engineers, and indeed to young men in all walks of life.

Mr. Corey is married and resides at the Lorraine apartments, New York City; he has one son, now attending college. He is a member of the Union, Duquesne and Country clubs of Pittsburg, Pa., and also of the Metropolitan and Lawyers' clubs of New York City.

Thomas Messenger Drown. — By the sudden death of Dr. Drown on November 17, the world has lost an eminent scientist, a successful educator and a man of warm sympathies and lofty ideals. The following short biographical sketch is by the pen of Dr. R. W. Raymond:

"Thomas Messenger Drown was born at Philadelphia, Pa., March 19, 1842. Graduating from the Philadelphia High School in 1859, he entered the medical school of the University of Pennsylvania, and received in 1862 from that famous school the degree of doctor of medicine. For a brief period he practiced his profession as a physician, making during that time, I believe, one or two voyages as medical officer of an ocean steamship. But he seems to have been attracted neither by therapeutics nor by surgery, whereas chemistry, which he had studied incidentally as part of his medical course, had a strong fascination for him, and following this call, he definitely abandoned his practice as a physician and resumed the position of a student, taking special courses in that science at Yale and in the Lawrence Scientific School of Harvard University. After this

he spent some years abroad as a student at the University of Heidelberg and the Royal Mining Academy of Freiberg, Saxony, where he devoted himself, under the great teachers of that generation, to chemistry as applied to metallurgy.

" Returning to the United States thus fully equipped, with a technical preparation not to be acquired at that time in this country, he practiced for some years in Philadelphia as an analytical chemist, and in 1875 accepted the professorship of chemistry at Lafayette College, Easton, Pa. In 1885 he assumed and retained for more than ten years a similar position in the faculty of the Massachusetts Institute of Technology at Boston. During the latter period he planned and executed what was, perhaps, the most useful and memorable achievement of his scientific career, namely, the systematic investigation (involving several thousand chemical analyses) of the spring and well waters of Massachusetts, and the preparation, on the basis of these analyses, of the famous ' chloride-map ' of that state, from which it can be determined at a glance how much chlorine, found by the analysis of water from a given locality, can be considered as due to the salty breezes of the Atlantic, and how much should be regarded as indicative of organic contamination.

" In 1895 Dr. Drown accepted the presidency of Lehigh University, at South Bethlehem, Pa., and that position he occupied for the rest of his life, winning and deserving the love, respect and admiration of all by his executive ability, tact and wisdom. Dr. Drown was secretary of the American Institute of Mining Engineers from 1873 to 1883."

Joint Investigation into the Metallurgy of Steel. — The following circular, dated November, 1904, has been sent by Mr. R. T. Glazebrook, director of the National Physical Laboratory (Teddington, England), to interested persons:

Sir, — With a view of commencing preliminary work in connexion with the above investigation, I beg to send you the following memorandum drawn up by M. Le Chatelier, and to ask for your remarks on it. If you approve the scheme, I should be glad to know further if you are prepared to assist in carrying out the experiments.

Researches on the Constituents of Steels

Preliminary Investigations as to the Conditions under which Quenching should be Performed

Before studying the properties of the constituents of steels, it is necessary to define precisely the conditions under which each of them can be obtained. The constituents as to which there exists the most uncertainty are those of quenched steels. Distinctions have hitherto been made between these based chiefly on metallographic characteristics. Accordingly, preliminary experiments to ascertain the conditions of production of these constituents will be principally those of quenching, followed by metallographic examination of the quenched metals.

The preliminary investigations will doubtless involve the use of a considerable quantity of metal, and it does not seem to be indispensable, at any rate at the outset, that they should be made everywhere upon the same specimens. It will be less costly for each laboratory to take steel specimens to which it has access. In this way a strain will not be put upon the good will of works to whom it will be necessary to apply for large quantities of metal for the final experiments.

The preliminary studies may be divided into two parts:

(1) **Study of the Conditions of the Production of Austenite.**

This should be taken by itself on account of the special difficulties it presents and of the more complicated method of procedure it will demand. This question is the first to take up, for it appears probable that all the constituents of steels are derived from a series of transformations of austenite.

(2) **Study of the Conditions of Production of the other Constituents of Quenched Steels.**

(*1*) *Study of the Conditions of Production of Austenite*

According to present knowledge, this constituent is obtained the more easily the more carbon the metal contains, the higher the temperature to which it is heated, the lower the temperature of the bath in which it is quenched. On the other hand, this constituent is very rapidly destroyed by heating to 150° C., and perhaps slowly at the ordinary temperature. In

any case one and the same specimen, if polished several times, gradually alters its appearance. This result may perhaps be due to two causes, — either the heat generated by polishing, in spite of precautions that may be taken, or the mechanical action of rubbing.

The programme suggested is as follows:

Steels with 1.4, 0.9 and 0.6 per cent carbon.

Specimens of 20 millimeters ($\frac{4}{5}''$) diameter, and of the following lengths: 2 mm. ($\frac{1}{12}''$), 10 mm. ($\frac{2}{5}''$) and 50 mm. ($2''$).

The last named is to be notched to a depth of 1 mm. ($\frac{1}{25}''$), to allow of its being split after quenching, in order to examine the central part of the cylinder. One surface should be polished before heating to reduce to a minimum the work to be done after quenching.

The heating to temperatures from 1000° to 1200° should be performed in such a way as to avoid superficial oxidation of the metal. A lead bath has been suggested for this purpose.

Duration of heating — 1 minute, 5 minutes and 1 hour.

Quenching to be effected if possible in a completely liquid bath of calcium chloride solution at —50° C.; or, in default of this, in a brine bath at —20° C.; or, in default of this, in water at 0° C. Cooling might be obtained by the aid of liquid carbonic acid. In any case freezing mixtures containing solid fragments of salt or ice must not be employed because they oppose the free circulation of the liquid and give very irregular results; sometimes the quenching is less thorough than in water at the ordinary temperature.

Polishing is to be done entirely by hand. Emery grindstones and felt discs are not to be used. Polishing should be performed on a wetted surface, *e. g.*, emery papers moistened with terebenthene oil can be used. With these very rapid work can be done.

Finally, the conditions will be studied under which the destruction of austenite takes place by heating at definite temperatures, and during a definite time period.

It should be understood that all the experiments indicated here may not be necessary. By commencing with steel 0.6 per cent carbon of 2 mm. thickness and quenching at 1200° C., if no trace of austenite is found, it is useless to proceed further with the same steel.

It would, however, be very interesting if those investigators within whose power it lies were to make quenching experiments on small specimens of metal, subjected to industrial cementation, the quenching being performed at the exit of the cementation furnace without any previous cooling. Splendid austenite is thus obtained whose magnitude greatly facilitates its examination.

In order to characterize the austenite two characteristics will be employed, — those of chemical attack and of hardness.

Chemical Attack. — The two reagents which seem to give the best results are picric and nitric acids dissolved in various alcohols, the concentration, temperature and duration of attack being specified. It would be very useful to define the most advantageous conditions of attack, but they will probably vary a little with the manganese and silicon contents of the steels. Experiments might be made with the two following reagents, recently described by Mr. Kourbatow as particularly interesting:

(1) A 4 per cent solution of nitric acid in iso-amyl alcohol.

(2)	Concentrated hydrochloric acid	5 parts.
	Iso-amyl alcohol	20 "
	A saturated solution of nitro-aniline or ortho-mono-nitro-phenol in ethyl alcohol	75 "
		100 parts.

Hardness. — The difference between the hardness of austenite and that of martensite, which always accompanies it, will be tested by scratching either by means of very fine points of more or less hard materials and subjected to varying pressures, or by means of powders of different hardness. The excellent results obtained with the specimens prepared at the exit of the cementation furnace are superior to those obtained with laboratory specimens, and this characteristic, which is one of the best of austenite, is easily spoiled.

(2) *Study of the Conditions of Production of the Other Constituents of Steel*

The same dimensions of specimens:

To the three preceding series of steels, two more will be

added, with 0.2 per cent and 1.8 per cent carbon. These latter will be useful in defining the conditions of production of troosto-sorbitic structures, which are still more obscure than those of austenite.

To the preceding quenching temperatures a complete series between 600° and 800° C., both on heating and cooling, is to be added for the study of troostite. Quenching in water at the ordinary temperature should suffice. To the etching reagents previously mentioned will be added the two following, particularly recommended by Mr. Kourbatow for the study of troosto-sorbitic compounds:

(1)	Methyl alcohol	25 parts.
	Ethyl alcohol	25 ,,
	Amyl alcohol	25 ,,
	A 4 per cent solution of nitric acid in acetic anhydride	25 ,,
		100 parts.
(2)	A 4 per cent solution of nitric acid in ethyl alcohol	25 parts.
	A saturated solution of ortho-mono-nitro-phenolin ethyl alcohol	75 ,,
		100 parts.

It is probable that in these cases the duration of heating will have to be particularly studied.

The troosto-sorbite, which is obtained in steels with more than 1 per cent carbon quenched above 1000° C., is always grouped around the cementite, seeming to indicate that there has not been time for the diffusion of the latter to take place in a uniform manner throughout the whole mass.

It is suggested that these studies should be extended over a period of about six months, and that the results should then be published.

The Electric Smelting of Iron Ore. — The report of the Canadian commission appointed to investigate the electrical processes of smelting iron ore gives no hope of early results of wide import to the iron trade. The commission has gone into the question very thoroughly, having visited electro-thermic smelting plants in Sweden, France and Italy, as well as the

experimental plant at Lockport, N. Y., witnessing practical tests at each place under the supervision of its own electrical and metallurgical experts, and securing data of costs of operation. It finds that the processes aiming to turn out steel give no promise of competing with the Bessemer or open-hearth, as the output is necessarily limited, and therefore they seem only adapted to producing the highest grades of steel, similar to the crucible product. It is stated that such grades can be made by the electric process at a lower cost of production than by the crucible process, but this is, of course, only the case where electric energy can be had cheaply. With regard to the smelting of pig iron, it is found that while none is being manufactured commercially the results thus far experimentally accomplished lead to the conclusion that electro-thermic furnaces can be successfully designed for the accomplishment of this purpose, and that the perfect control of the temperature in such furnaces will enable pig iron to be produced of the precise grade desired. The electric production of pig iron, however, can only be accomplished commercially in localities in which electric energy is to be had at very low cost, and in which coke or other furnace fuel is dear. It was hardly necessary for the report to state that no general rule could be laid down to govern ventures of this character, special investigation being needed in every locality to determine its possession of the essential requisites for economical operation. The metallurgical world is under great obligation to the Canadian government for the flood of light which it has thrown upon this interesting subject. Not that a great deal of what is stated in the commission's report had not been known before. Much of it had found its way into print. But the information thus given was disjointed and often lacked the desirable element of authenticity which is here supplied. Above all, the fact is now made plain that thus far the adventurers in this new field of metallurgical work have accomplished nothing which even faintly suggests the revolutionizing of existing methods in the iron and steel industry. Such a glamour invests the use of electricity, as it has accomplished such wonders in the very short time since man learned to harness it, that the world had almost brought itself to believe that somebody somewhere was solving the problem of reducing ore to pig iron or to merchant steel practically without fuel and at

almost no cost. The publication of the Canadian commission's report will not lead to the immediate investment of much capital in the electric smelting of iron ore. "The Iron Age," November 10, 1904.

Electric Smelting of Iron and Steel. — The final report of the commission appointed by the Canadian government to investigate electro-thermic processes for the smelting of iron ores and the making of steel has been issued. The commission consisted of Dr. Haanel, Dominion inspector of mines; Thomas Cote, assistant census commissioner; C. E. Brown, of Peterborough, Ont., electrical expert; Mr. Nystrom, draughtsman, with F. W. Harbord, an English metallurgist, as consulting engineer. The party visited the works at Gysinge, Sweden, where scrap iron is converted into steel by the Kjellin process at a cost of $34 per ton; La Praz, France, where steel is made from scrap at a reported cost of $14 per ton; and Turin, Italy, where the Stassano process was examined. It was there ascertained that the cost of a rotating furnace would be $5,000, and its output four or five tons daily.

The most important investigations, however, were made at Livert, France, where three experiments were carried out for the benefit of the commission: (1) Electric reduction of iron ore, and obtaining different classes of white, gray and mottled pig. (2) Electric reduction of iron ore to ascertain the amount of electric energy absorbed in the production of one ton of pig iron. (3) The manufacture of ordinary steel of good quality from the pig iron. It was ascertained as the result that the cost of a ton of pig iron produced from 55% hematite ore was $10.71. The experiments at Livert show that it requires 9,750 electric horse-power at the electrodes to produce 100 tons per day.

Many of the details embraced in the final report have been given already in preliminary statements, the most noteworthy feature now presented being the difference between the conclusions of Dr. Haanel and Mr. Harbord. This is accounted for by the fact that the former had in view the special local conditions of the Ottawa valley, while the latter's deductions are of a general character.

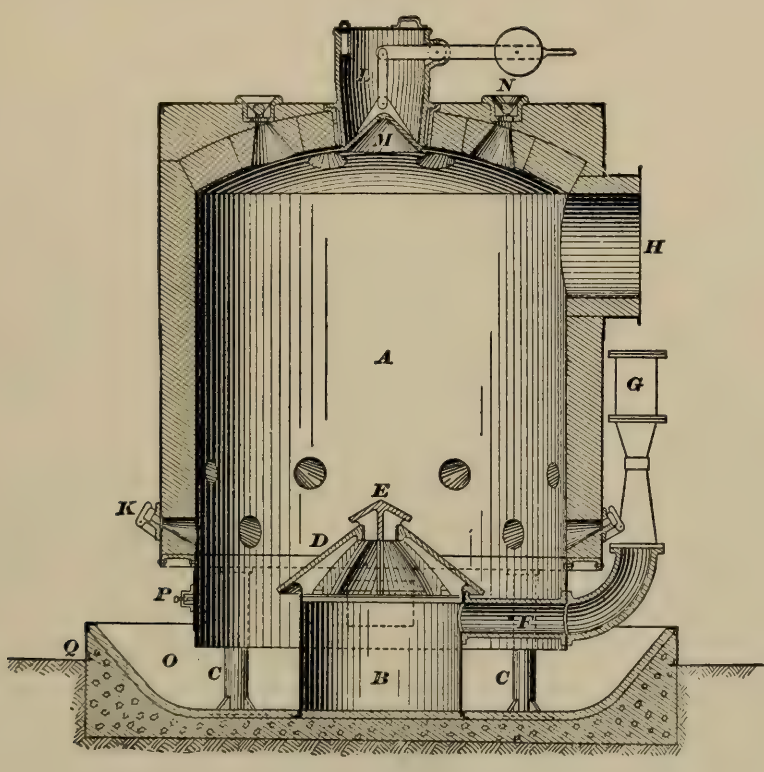
Mr. Harbord's opinion, based on the experiments and

observations of the commission, is that steel equal to the best Sheffield crucible steel can be produced either by the Kjellin, Heroult or Keller process, at a cost less than the expense of producing a high-class crucible steel by present methods. That at present, mild steel, suitable for structural purposes, cannot be produced to compete with Bessemer or open-hearth steel; that pig iron can be produced on a considerable scale to compete with the blast furnace only when the electric energy is very cheap and the fuel very dear. On the basis of $10 per horse-power per year, and coke at $7 per ton, the cost of production is about the same as the cost of making pig iron in a modern blast-furnace. "Under ordinary conditions," he concludes, "where blast-furnaces are an established industry, electric smelting cannot compete; but in special cases, where ample water power is available, and blast-furnace coke is not readily obtainable, electric smelting may be commercially successful."

Dr. Haanel expresses the view that where, as at Chat's Falls, near Ottawa, electric power is produced, as he is told it can be, at $4 per horse-power per year, and peat coke, or briquetted charcoal, made from mill refuse, at an expense of not more than $4 per ton is used, the cost of the two heaviest items entering into the production of pig iron is reduced by one half. "When it is considered," he goes on to say, "that the electric process is applicable also to the smelting of ores such as copper, etc., and that the furnaces are of simple construction, the temperature available 1000° C. above that of the blast-furnace, and the regulation of the heat supply under perfect control, it is reasonable to expect that the near future will witness great strides in the application of electric energy to the extraction of metal from its ores. Familiarity with handling large currents and experience gained in electric smelting will result in solving the difficulties encountered in the smelting of ores, which up to the present time have proven refractory to all commercial processes known." "Engineering and Mining Journal," November 10, 1904.

The Amsler Gas Producer. — The question of fuel for firing furnaces of all kinds has ever been a vexatious problem. When the use of natural gas is impossible, or unprofitable, the usual

recourse is to the use of coal or gas made from coal, and in fact in some cases when the required degree of heat can be obtained only by regeneration, producer gas is especially economical and convenient. The gas producer is a simple piece of apparatus, and gas can be generated in any retort that will stand from 1800° to 2000° temperature and is provided with an air blast. However, a producer must be operated continuously, sometimes for weeks at a time. It must be built so that coal can be fed and the ash removed continuously without disturbing the output of gas. Clinkers will form and they are troublesome, and in cases when the ash is easily fusible, the clinkers are particularly troublesome.



Amsler Gas Producer

The illustration shows a producer constructed to meet these requirements. The gas producer chamber A is made of a firebrick-lined and domed steel shell, supported on the four columns C. The coal is fed into the producer through the covered hopper L and bell M, and the ashes are removed through the water seal in the pan O. This seal is effected by filling the

pan O with water. The apron at the bottom of the producer shell then dips several inches into the water and prevents the escape of gas or air through the ashes.

The air is distributed under and through the incandescent fuel bed by the double hood D and E. These are supported on the steel standpipe B. The air is blown into this standpipe through the pipe F by the special multiple nozzle blower G. There are sixteen poker holes K distributed around the sides, and six on top.

This is a water-sealed gas producer designed to combine high efficiency, accessibility and low cost of installation and repairs. No grates enter into the construction, neither are any false bars nor fire cleaning doors required. There is no chance for the air to pass up the side of the producer and burn the gas above the fuel. The air distributor thoroughly introduces the air throughout the bed of ashes below the fuel, so that the fuel is completely consumed. When the ashes are taken out they are cooled to almost atmospheric temperature. All these items contribute to large gasifying capacity for the bosh area.

One large blower is used because it requires less steam for the same quantity of air blown into the producer than do a number of smaller ones. By introducing the air through the pipe F above the water, it is impossible for the condensed steam to collect and trap off the air supply.

The loss by radiation is reduced to a minimum as the circular cross section presents the minimum surface for a given volume of fire. The top is made of a brick dome, which also reduces the loss by radiation and makes the gas house more comfortable. Aside from the six poke holes in the crown of the producer, there are sixteen additional poke holes staggered around the side of the producer. These are used as sight holes to keep the fuel bed even, as well as to dislodge and break up clinkers, and are useful to prevent holes forming in fuel bed. They are of convenient height to be accessible from the floor.

There are, in addition to the above-mentioned poke holes, four doors in the ash apron for the removal of large clinkers which may prove troublesome to remove through the water seal, and for access to producer for repairs or other reasons.

As the ash pan is circular in shape, it allows the ashes to be removed from any side of the producer, so that there is no

trouble in keeping the fuel bed level and the depth of the fire the same throughout the producer. One man can clean a large number of producers.

The producer is of simple construction. The sides of the producer are straight all the way down to the ashes, and the poker bars cannot strike any projections on the side of the brick work, and the removal of clinkers is convenient. This producer is made by the Amsler Engineering Company of Pittsburg. "The Iron Trade Review," October 27, 1904.

The Martin Method of Making Pig-Iron Molds. — A recent issue of the London "Iron and Coal Trades Review" describes a method invented for expeditious work in making pig-iron molds by J. T. Martin of Martin & Son, malleable iron founders, Vine Street, Lambeth, England. Mr. Martin's patent provides for mold beds being prepared between two rails by loosening up the sand and straking it off level with the rails. A roller having journals bearing on the rails is passed over the loosened sand, and compresses it, while ribs extending round the periphery of the roller form channels in the compressed sand of the desired sectional dimension. The molten metal is run into the channels, and afterward, when solid, broken into the desired lengths.

Fig. 1 is a side elevation of the roller, Fig. 2 is an end elevation, and Fig. 3 is a transverse section of the finished mold. The rails A are laid parallel on wooden beams B and arranged to form a trough of any desired length in which the molding sand D is laid. The beams B are faced on the inner side with plates C. A roller, E, is employed for channeling and compressing the sand in the trough. For this purpose the roller is provided with a number of annular channeling ribs I of a cross section corresponding to that desired for the pigs to be cast, and is mounted on the rails A and adapted to be traversed along them over the entire length of the trough, grooves or treads F being formed on the ends of the roller to guide and support it on the rails. As shown, the ends of the roller E are reduced in diameter to enable the ribs and compressing surfaces of the roller to bear upon and properly channel and compress the sand between the rails. A frame G mounted on journals H is connected by means of a chain or other connection with a hand or power device adapted to traverse the roller along the

rails. In preparing the mold, the sand is brought level with the top of the rails; the roller is then passed over the sand and compresses it, and, by means of the ribs, forms therein the

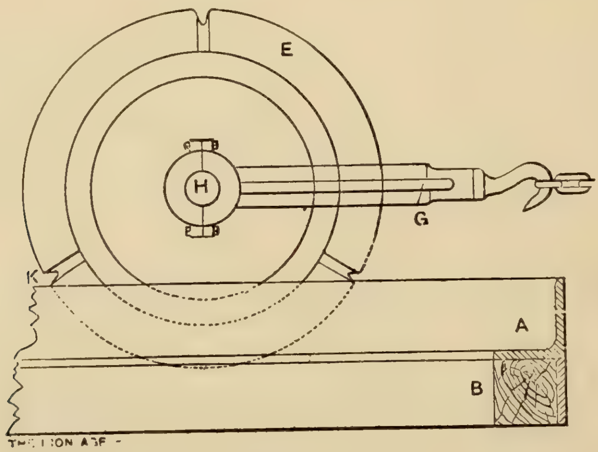


Fig. 1.

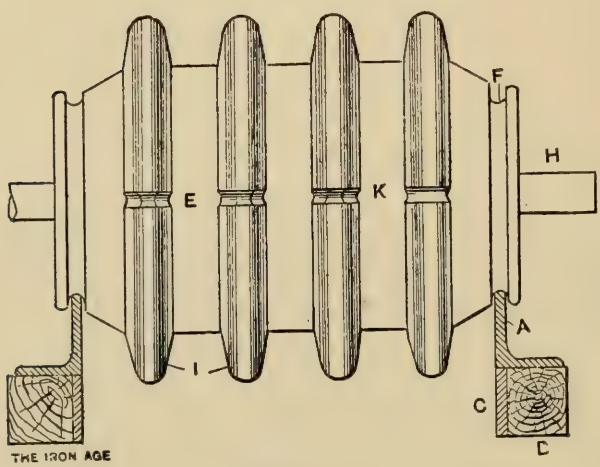


Fig. 2.

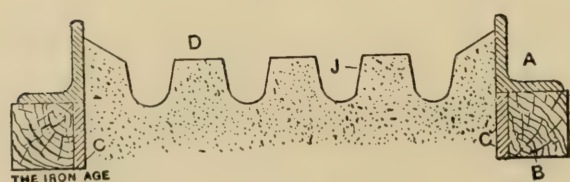


Fig. 3.

The Martin Method of Making Pig-Iron Molds

channels or furrows J for receiving the molten metal to form the pigs or castings. The channels J receive the molten metal from a channel common to all, formed at one end of the trough.

To facilitate the breaking of the pig iron into lengths, notches K are cut in the annular channeling rings.

With this arrangement no skilled labor is required to manipulate the roller, and it is claimed that a large saving in time over the ordinary method of molding is effected. "The Iron Age," November 10, 1904.

American Enterprise. — No doubt the changes in the American iron trade since the last visit of the Institute in 1890 have been very great. Fourteen years ago the Mesabi range, with its hundreds of millions of high-grade ores, was undiscovered. The American tin-plate industry had no existence, and the use of steel in construction work to replace wood and stone had scarcely begun to expand. The United States Steel Corporation was not thought of. Add to what is expressed in these three sentences all that is embraced by the rapid evolution of "American practice" in iron and steel making, not omitting the stride from 62 to more than 80 millions in population, and we have summarized to a large extent the causes of the advance comprehended between 1890 and 1904. Nature has combined with the engineer, the manager, the legislator and the latter-day financier to produce the result. Alluding to this subject, "The Iron Trade Review," of Cleveland, Ohio, says: "Fourteen years ago the British and German visitors studied the American iron and steel industries with two questions in mind: (1) Whether the iron and steel works of the United States would be able to meet all domestic needs and make iron and steel imports practically unnecessary. (2) Whether the United States would ever become a competitor in iron and steel in markets apart from the Western hemisphere. The first question was generally answered in the affirmative, the second in the negative. Sir Lowthian Bell, in his exhaustive commentary on the American iron industry as he found it in 1890, concluded that it was improbable that with pig iron costing $13 at Pittsburg, and a freight of $2 to seaboard, there would be any competition with Great Britain from the older seats of the American iron industry, except in countries close to the United States. The developments of the past fourteen years in American iron and steel making have swept away Sir Lowthian's premise, and with it has gone his conclusion. It is

no longer $13 pig iron at Pittsburg with which such calculations have to do, but with a $13 steel cost and lower. And all theories and census statistics and paper costs give way before the hard fact that to-day the steel billet and finished product exports by the United States Steel Corporation are at the rate of more than 1,000,000 tons a year, or about one eighth of its entire output, and a round tonnage of it going into the British Isles themselves. Since 1890 Germany, then a trailing third in the international race, has forged into second place, and has become the real competitor of the United States, gauged by ability to attain low cost on a large proportion of its output. Minette ores and a maximum saving on fuel bills through by-product recovery and large use of gas for power, have been large offsets to the richness of Lake Superior ores and Connellsville coal. In fact, those who have canvassed the relative positions of Great Britain, Germany and the United States, based on the cost of steel put into cars at works, have found German works to which they were willing to award the palm. But perhaps there has been too great a tendency to reduce the question of the future of the three leaders in the race for supremacy in iron and steel to one of assembling and manufacturing costs. Other factors of importance have too often been left out of the account. The United States will continue indefinitely to be the largest consumer of iron and steel, gross and per capita. That fact will always count tremendously in favor of the home manufacturer. It will be many years — if the point is ever reached — before he must look to foreign trade for any important fraction of his profits. The government policy of raising revenue by the indirect method of a protective tariff will count heavily in his favor. The elimination of weak producers of iron and steel through the consolidation movement of recent years must be reckoned no small factor in the international problem. Freed from the drag of weak or bankrupt properties, the American iron trade was never surer of reasonable profits at home. The industry in Germany will have important benefits in this direction as the result of recent movements." "Iron and Steel Trades Journal," November 19, 1904.

Selling Pig Iron by Warrant. — For many years it has been the custom in Great Britain to store a large part of the pig-iron

production, especially that of the Middlesborough district and Scotland, in public warehouses, and to sell the iron by means of negotiable warrants. These warrants passed from hand to hand and were usually good for deliveries at any of the storehouses. They served a convenient purpose in a country where deliveries did not extend over a wide range of territory, especially at a time when the grade of pig iron was not as close as it has become in recent years. Moreover, they became a handy tool of speculation, and, as many of our readers doubtless recall, fluctuations in pig-iron warrants have been very great, and there have been times when actual possibilities of delivery were largely oversold. Such speculative transactions, however, were not for actual consumption, but settlement was made by the payment of differences, as in transactions on the stock exchange.

Nearly fourteen years ago the American Pig Iron Storage Warrant Company, with George H. Hull at its head, was organized, and established storage yards in different places, its avowed purpose being the introduction of a warrant system of selling iron in this country. For various reasons, however, the system was not kindly received by our ironmasters, and although the company at different times has stored a good deal of iron in its yards, especially in the South, the transactions in warrants have never come into vogue. An attempt was made some three years ago to deal in the warrants on the New York Metal Exchange, but the limited facilities of that exchange were not favorable, and transactions amounted to very little. Another decided effort to introduce the system has now been made, and this week dealings in pig-iron warrants commenced on the New York Produce Exchange, where there will be a fair chance for the development of the system. The rules adopted there, and the methods of dealing, are fully explained in our market columns.

We doubt very much, however, whether this new move will be a successful one. It will not affect, to any extent, the basic and Bessemer iron, which constitute two thirds of our production. By far the greater part of this is made by the large steel companies for their own use and does not come into the market at all; while that which is made by outside furnaces is generally sold direct to the steel companies in large lots, and those companies would not be likely, in any event, to come into the warrant market. There remains a limited quantity of forge and

foundry iron which is open to dealing in this way; and we believe that the large buyers of these grades of iron would prefer to contract directly with furnaces, as they have been in the habit of doing, rather than to go into an iron market and buy a given number of warrants, however easy it may be to secure delivery upon them. Small buyers will not be attracted, but will rather be repelled by the intricacies of the exchange transactions and the necessity of paying brokers' fees. Moreover, rightly or wrongly, there is a preference among most foundrymen for special brands. This frequently depends largely upon habit and individual liking, but it nevertheless exists, and may prove a considerable factor. Experience alone can show whether these points will prove enough to limit the new method.

Another point to be considered is that the warrant system may open the way to speculation in pig iron to an extent which has not before existed. There has been at different times speculation of this kind, of course; but it has been limited to comparatively few parties, who were directly connected with the iron trade, and were able to handle large quantities. Warrant dealing on the exchange will make it possible for smaller speculators to trade in iron as they have done in stocks and grain. This may lead at times to fluctuations which are undesirable for the trade in every way. While the standing of the produce exchange gives a certain desirable guarantee to transactions, and while the rules appear to have been carefully framed, the introduction of a purely speculative element is more apt to unsettle quotations than to regulate them, as the advocates of the system claim. "Engineering and Mining Journal," November 17, 1904.

The Development of the Forging Press. — The persistence in the use of the hammer for the purpose of forging iron is an excellent example of the manner in which mechanical practice has been diverted from the true logical line of development because of the influence of precedent. The hammer was undoubtedly the best tool for use by the human arm, therefore, when power came to be applied to the same work a bigger hammer was used, the details of the old-fashioned tilt hammer following the construction of the hand hammer as closely as the early railway carriages copied the lines of the stage coach. Even

when Nasmyth broke the precedent by designing a steam hammer without a handle, he failed to realize that the true method of forging was by use of Bramah's hydraulic press, a machine which had already been perfected for other work and was ready to his hand. It was not until the magnitude of the work reached limits which made it apparent that the time element entered into the operation, and that a quick blow did not affect the interior of a mass to a sufficient extent, that engineers turned to the method of forging by pressure instead of impact.

In recent issues of "Glasers Annalen" the development of hydraulic forging machinery is discussed at length in an admirably illustrated article by Baumeister Peter, and from this we make some abstracts, reviewing the salient points.

The use of pressure in iron working appears in other departments than forging at an early date. The operations of rolling are also processes of working by pressure, but the first use of direct pressure appears in the employment of the "squeezer" for the expulsion of the slag from the puddled metal. Various forms of squeezers were used, the earlier types being of the alligator model, again following precedent and using what was really an enormous pair of pincers, operated by a cam movement, for compressing the ball of hot metal between its jaws. Later the rotary squeezer was designed, the metal being rolled through a gradually diminishing space between a fixed housing and an eccentrically placed roll. The hammer maintained its supremacy for forging, however, until it became evident that external pounding of large masses acted only to condense the exterior portion, leaving the interior nearly in its original open and porous condition.

The development of hydraulic forging and other forming operations by hydraulic pressure was greatly advanced by the introduction of the hydraulic accumulator. This avoided the necessity of using a pump capacity otherwise required for the maximum demand, besides equalizing the load and giving a smoother action to the ram of the press than by direct pumping.

Herr Peter illustrates the development of the forging press by showing the various forms successively, although the machines given are principally from German practice. The earlier presses of Haswell and of Whitworth are shown, followed by the improvements of Davy, Fielding and Platt, Krupp, Haniel and

Lueg and others, and the attention which has been given to detailed improvements is very clearly exhibited. Thus it was soon found that a marked economy in water was effected by using small auxiliary cylinders for raising the ram after a pressure stroke had been made, this arrangement also enabling a quicker return stroke to be made. Various arrangements of cylinders have been adopted by different builders, but in general the forging press consists of a massive upper and lower yoke, connected by strong columns, one yoke carrying the cylinder, with its ram, and the other supporting the anvil, as it may be termed, the pressure being opposed by the rods which tie the two yokes together. Some presses have more than one ram, and the minor details are modified to suit the nature of the work.

Modern accumulators permit the use of working pressures ranging from 2,500 to 10,000 pounds per square inch, the total effort exerted by the ram reaching, in the case of the great press at the Krupp works, as high as 5,000 tons; while the press at the Bethlehem Steel Works exerts a total pressure of 14,000 tons.

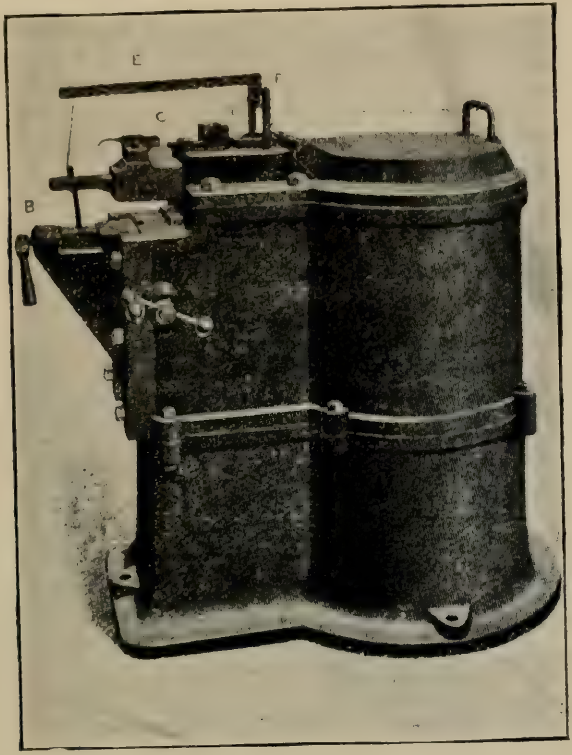
Herr Peter reviews the auxiliary arrangement for use in the working of hydraulic forging presses, including the furnaces for heating the metal, the various handling devices, cranes, hoists, etc., giving an excellent idea of modern practice. He also gives a number of examples of the manner of working large shafts, armor plates, and other pieces of forge work, with illustrations.

In addition to the use of hydraulic power for forging, it is coming into use for shearing heavy masses, such as armor plates, and also for operating forming presses for shaping heavy boiler plate for boiler heads, and for special shapes. The bending press is also found valuable for curving the heavy plates required for the shells of marine boilers of the Scotch type, and for shaping armor plates for special positions, such as the protection of turrets, babettes and conning towers of battleships.

The paper of Herr Peter is a satisfactory contribution to a department of modern shop practice concerning which but little has been published, and such articles are to be welcomed as useful additions to technical literature. "The Engineering Magazine," November, 1904.

Professor Arnold's Steel Tester. — We have already illustrated diagrammatically the alternating stress machine devised by Professor Arnold for carrying out tests of the Wohler type. We now illustrate the actual machine from a photograph as made by Messrs. Ibbotson and Green, Wellington Works, Sheffield.

The machine is coupled direct to a three horse-power motor, and motion is imparted to a vertical shaft by a bevel wheel and pinion in the proportion of 4 to 1. The top of the shaft is



Testing Machine

recessed out and an adjustable nut fitted therein, which, carrying a pin, imparts the necessary to-and-fro motion to the ram A. The nut can be adjusted, altering the crank length, and giving 3 in. stroke and downwards by thirty-seconds of an inch. The plate B is made a sliding fit in the ram A, so that full speed may be attained before the test commences.

The test piece being in position, the machine is started, when the catch C is dropped, and, engaging in a slot in the plate B, bending is commenced. The test piece is held, as can be

seen in the engraving, in dies of the size required, which are clamped in a vertical sliding table, so that the length of test piece may be varied.

The lever arm E is connected directly by a wire to the test piece and speed counter D, and is held in tension by the spring F, its object being that, when the test piece breaks, the lever flies up and cuts off the speed counter at the same instant.

We may state that the motor can be varied between 1,400 and 700 revolutions per minute, so that the number of alternations may be varied accordingly. "The Engineer," September 27, 1904.

Manganese Ore in India. — The official report for 1903 of statistics of production in India says that the most remarkable development has taken place in recent years in the mining of manganese ore in that country. This industry commenced little more than ten years ago by quarrying in the deposits in the Vizianagram State, and from an output of 3,130 tons in 1893, the production rose rapidly to 87,126 tons in 1899, when the richer deposits in the Central Provinces were also attacked, and are now yielding a larger quantity of ore than the Vizianagram mines. In 1903 the total output reached a record of 171,800 tons, which places India among the first two of the countries producing high-grade manganese ore. The ore raised in the Central Province is of very high grade, ranging from 51 to 54 per cent metal, and in consequence of its high quality is able to pay the heavy tax of freight over 500 miles of railway, besides the shipment charges to Europe and America, for the whole of the ore is exported, to be used principally in steel manufacture in Great Britain, Germany and the United States. By far the largest proportion of ore is raised in the Nagpur district, though work has been begun in the districts of Bhandara and Balaghat, while prospecting operations are in progress in the Chhatisgarh district, in the Jhabua State in Central India, and a few other places, besides Vizianagram, where mining still continues. The work hitherto has been little more than quarrying, and no approach to exhaustion can be said to have occurred in the chief deposits, which, however, are being worked for the highest grade of ore only. In the Nagpur area and in Vizianagram the ore occurs as lenses in the gneisses and schists, attain-

ing a length in one case of six miles, and thickness, in the case of pure ore bodies, of over 100 feet. Layers of nodules also occur as the result of the removal of crystalline limestone, through which the nodules were originally disseminated. In the Jubbulpur district the ore is of a lower grade, and is generally a manganiferous limonite, formed by the alteration and concentration of the manganese in the hematites which occur as constituents of the Dharwar (Archean) schists. The most prominent, and sometimes the only mineral in the purest ore-bodies is braunite, which is often accompanied by psilomelane. In parts of the Deccan plateau, manganese ore occurs as nodules formed by concentration of the oxide in the decomposition products of the great basaltic lava flows. "Iron and Steel Trades Journal," November 19, 1904.

By-product Coke Gas for Open-Hearth Steel Making. — At the South Sharon, Pa., plant of the Carnegie Steel Company, gas from the by-product coke plant has been connected with one of the open-hearth furnaces for the purpose of utilizing it in the place of producer and natural gas. If the experiment proves successful all of the other furnaces will be connected as well as the heating furnaces and soaking pits. The by-product plant, in addition to supplying its own boilers with gas, has a surplus of about 3,000,000 cubic feet per day, and this can be utilized to good advantage in the operation of the steel plant. During the first half of November the nine furnaces in operation produced 13,450 tons of steel, one furnace producing 1,850 tons in fourteen days, while another produced 1,844 tons in thirteen days. The erection of a mixer at this plant is now contemplated, as the iron from three blast-furnaces is used in the open-hearth department. "Iron Trade Review," November 24, 1904.

Steel Ties. — The Carnegie Steel Company, Pittsburg, is now turning out steel ties on a commercial basis at the Homestead Steel Works. These ties are designed to supplant the ordinary wooden ties; and while the initial cost is somewhat higher than that of the wooden tie, this is more than offset by the longer life of the steel tie. These steel ties weigh $19\frac{3}{4}$ pounds each, are $4\frac{1}{2}$ inches wide on the top and $7\frac{1}{2}$ inches wide on the

bottom, while the web is from five-sixteenths to three-eighths inches thick. The company has recently furnished 7,000 of these ties to the Lake Shore and 5,000 to the New York Central roads. "Iron and Steel Trades Journal," November 19, 1904.

New Blast-Furnace Records. — While at Duquesne the Iron and Steel Institute visitors were apprised of new world's pig-iron production records. Furnace No. 1 of this group of four stacks produced 793 tons on October 27, exceeding all previous records for this plant, and the output of the four stacks during the month breaks all records of any four blast-furnaces during a similar period. The four stacks produced 74,608 tons of iron, while the best previous record was 74,192 tons in January, 1902. The furnaces making this latter record included two at the Carrie plant, one at Edgar Thomson and one at Youngstown. On October 27 the four stacks in the Duquesne group produced 2,700 tons of iron, and during the week of October 22 to 29 furnace No. 1 had an output of 5,001 tons. During the entire month this stack produced 20,659 tons, while the weekly average of the four was 17,783 tons. The bulletin containing this information also said that one of these furnaces produced 1,287,381 tons of iron on one lining, while the four furnaces produced 4,469,855 tons without change of lining. Furnace No. 1 was blown in on June 8, 1896, and is 100 by 22 feet. The iron from these furnaces is used in the Duquesne Steel Works, direct metal being taken to the steel works mixers. "Iron Trade Review," November 3, 1904.

REVIEW OF THE IRON AND STEEL MARKET

As the month of December has progressed there has been a decline in demand for finished steel products, but the decline has been less than is usually expected at this time, so that developments may really be regarded as favorable. As to the cruder lines, pig iron and steel billets, sheet bars, etc., it is difficult to say how great the demand really is since it is very difficult to secure these materials, and in many cases possible buyers refrain from making inquiries.

That there is on the part of producers an even greater confidence in the future than was noted in our last report is shown by the advances which have been made in December, some, as in pig iron, being an open-market movement; others, as in plates, shapes and merchant steel bars, being ordered by associations of manufacturers; and still others, as in sheets and tin plates, being merely the individual action of the leading interest, followed by the outside makers.

The advances which can be assigned to definite dates are:

December 8: All wire products, 5 cents per hundred pounds; galvanized sheets, 10 cents per hundred pounds; corrugated roofing, 5 cents per square.

December 19: All structural shapes, 10 cents per hundred pounds.

December 20: Plates, one-tenth cent per pound, with a change in the classification whereby widths over 14 and not over 24 inches were advanced two-tenths cent; Bessemer steel merchant bars, one-tenth cent per pound, and open-hearth merchant steel bars, five-hundredths cent per pound.

December 22: Tin plates, 10 cents per box; black sheets, one-tenth cent per pound; painted corrugated roofing, 5 cents per square; galvanized corrugated roofing, 10 cents per square.

The advance through the month in pig iron ranges from $1.00 to $2.00 per ton, according to grade, the sharpest advance having been in forge.

On December 10 the rail pool met and finally reaffirmed the prices of $28, at mill, for standard sections of steel rails in 500-ton and larger lots. This action has been followed by the placing of some rail orders for 1905 delivery, but the buying has been scarcely as active as was expected. The advance to $28 was made in the spring of 1901, and no change has been made since.

A glance at the year just ended is not out of place. It opened with the iron trade in an unsatisfactory condition, and no strong prospects of any great improvement. At the same time our review of a year ago expressed the firm belief that the iron trade had experienced a depression only, and had not entered upon a lean period comparable to that from 1893 to 1898. That there was no ground for optimism is shown by the fact that the market simply experienced small ups and downs during the first three quarters, there being a little spurt about February 1 and another about August 1, with intermediate sagging periods. Early in September an improvement, slight but plainly perceptible, developed, and this improvement has gained headway by almost steady increments until now, the advent of the usually dull period of December and January having but slightly diminished the rate of progress.

Orders have been freely placed of late, and furnaces and mills enter the new year with a tonnage of orders on books which is large for the time of year. Current production is actually larger than it averaged during our year of greatest prosperity, 1902, and with the large additions to productive capacity in two years the percentage of employment is almost as large.

Ore Movement. — The lake shipping season for Lake Superior ores has closed. The official figures of shipments from all ports on the American side show a total of 21,226,591 tons, a decrease of only 2,422,959 tons from the total of 1903, although before the opening of the season some predictions named a total as low as 13,000,000 tons. The all-rail movement is yet to be reported, and will probably be in the neighborhood of half a million tons.

Pig Iron. — Sales have been comparatively light in the month, as the great bulk of the output of merchant interests had already been sold through the first quarter. On account of the continuance of the drought in the Connellsville region pro-

duction has been hampered, and the cold weather has interfered with the movement of what was produced, so that furnaces have been in difficulties, leading to occasional bankings for a day or two. Some additional furnaces have been blown in by the merchant interests and by steel producers, and by the end of January the country will probably be making pig iron at the rate of 20,000,000 tons annually, if furnaces are not prevented from getting their normal output through coke difficulties. Early in December the United States Steel Corporation bought 25,000 tons of Bessemer pig from merchant interests at $15.50, valley furnace, — equal to $16.35, Pittsburg, — for December shipment. It may buy some January iron also. The Bessemer market advanced to $16 immediately after this transaction. Forge has been in particularly active request and the spread between it and other grades in now less than the normal. We quote the market as follows: F.o.b. valley furnace: Forge, $15.50 to $16; No. 2 foundry, $16.50; Bessemer and basic, $16.00. At Pittsburg: Forge, $16.35 to $16.85; No. 2 foundry, $17.35; Bessemer and basic, $16.85. At Birmingham: Forge, $12.75; No. 2 foundry, $13.75. At Philadelphia: No. 2 foundry, $17.25 to $17.75; standard gray forge, $16.25 to $16.50; basic, $15.75 to $16.00. At Chicago: Northern No. 2 foundry, $17 to $17.50; malleable Bessemer, $17 to $17.50.

Steel. — The action of the billet association at its meeting on December 19 in refraining from advancing the official price was unexpected. The feeling of the makers seemed to be that, as the market showed it was able to take care of itself, it was better to allow it to do so. It is impossible to buy steel except at premiums of from 50 cents to a dollar a ton, and as high as $2 premium has been paid; referred to the official prices of $21 on billets and $23 on sheet bars, f.o.b. Pittsburg.

Shapes. — The advance on December 19 makes prices as follows: Beams and channels 15-inch and under, angles 2 x 3 to 6 x 6 inclusive, and zees, 1.50 cents; tees, 1.55 cents; beams and channels over 15-inch, 1.60 cents. A considerable tonnage was booked before the advance.

Plates. — The new price schedule lowered the line of demarkation between wide and narrow plates from 24 inches to 14 inches, with a general advance of one-tenth cent a pound, making prices as follows: $6\frac{1}{4}$ to 14 inches wide, inclusive, 1.40

cents; over 24 inches wide, 1.50 cents. These prices apply to tank quality, quarter-inch and heavier.

Merchant Bars. — The advance on December 20 of $2 per ton on Bessemer and $1 per ton on open-hearth bars removes the spread which has heretofore been diminishing between the two classes of steel, putting both at 1.40 cents. Early this year the spread was made $1 per ton, or 5 cents a hundred pounds, or half as much as the previous differential. A large volume of business had been entered before the advance. Common iron bars are still stronger, and are now quoted at 1.60 cents, f.o.b. Youngstown.

Sheets. — On December 8 an advance of 10 cents a hundred pounds was made on galvanized sheets, and on December 22 a similar advance on black sheets, the market now standing at 2.30 cents for black and 3.35 cents for galvanized, No. 28 gauge. Corrugated roofing has been advanced, on the same dates, a total of 10 cents a square on painted and 15 cents on galvanized, making the market now $1.75 on painted and $2.95 on galvanized, for No. 28 gauge, per square of 100 square feet.

Tin Plates. — Demand for tin plates was very heavy until the latter part of December, and the advance of December 20, 10 cents a box, fell on a comparatively quiet market. The mills have a very large tonnage sold for the first quarter, and much of this business is recognized as speculative, since actual consumption of tin plate is always light in the winter. The leading interest is operating within a few per cent of its total of 242 tin mills. The new price is $3.55 per box on 100-pound coke plates, f.o.b. Pittsburg, or $3.50 net, the practice of allowing a 5-cent rebate having been practically abandoned.

Scrap. — There has been a further sharp advance in all grades of scrap, and there is almost a deadlock between dealers and consumers, the latter hardly being able to pay the prices asked. The leading interest bought 5,000 tons of heavy melting stock at $16.50 delivered Sharon, early in the month, and even higher prices are asked.

STATISTICS

The following interesting statistical tables are reproduced from the Annual Statistical Report of the American Iron and Steel Association, presented to the members October 31, 1904, by James M. Swank, general manager of the Association.

Imports of Iron and Steel. — The following table, compiled from statistics obtained from the Bureau of Statistics of the Department of Commerce and Labor, gives the quantities and values of our imports of iron and steel and manufactures thereof in the calendar years 1902 and 1903:

Articles—Gross tons.	1902.		1903.	
	Tons.	Values.	Tons.	Values.
Pig iron, spiegel, and ferro-mang....	619,354	$10,935,831	599,574	$11,173,302
Scrap iron and scrap steel..............	109,510	1,606,720	82,921	1,273,941
Bar iron..	28,844	1,286,238	43,393	1,904,469
Iron and steel rails........................	63,522	1,576,679	95,555	2,159,273
Hoop, band, and scroll iron or steel.	3,362	131,052	1,525	74,898
Steel ingots, billets, blooms, etc.....	289,318	7,943,818	261,570	7,331,299
Sheet, plate, and taggers' iron or steel..	7,156	545,739	11,557	540,272
Building forms, and all other structural shapes, fitted for use..........	....	....	8,865	256,265
Tinplates..	60,115	4,023,421	47,360	2,999,252
Wire rods, of iron or steel..............	21,382	1,033,074	20,836	1,028,977
Wire and wire rope, of iron or steel.	3,469	606,724	5,018	728,430
Anvils..	203	29,746	250	35,378
Chains...	576	55,456	373	62,481
Cutlery..	....	1,672,054	....	1,903,895
Files, file blanks, rasps, and floats...	....	80,280	....	82,939
Fire-arms...	....	953,801	....	687,917
Shotgun barrels, in single tubes....	....	263,882	....	198,126
Machinery.......................................	....	4,230,708	....	3,927,165
Needles..	....	417,429	....	466,294
All other..	....	4,076,174	....	4,421,291
Total.	1,206,811	$41,468,826	1,178,797	$41,255,864

Exports of Iron and Steel. — The following table compiled from the same source shows the exports of iron and steel in the calendar years 1902 and 1903.

Articles—Gross tons.	1902. Gross tons.	1902. Values.	1903. Gross tons.	1903. Values.
Pig iron	27,487	$502,947	20,379	$384,334
Scrap and old	9,411	149,013	8,034	117,972
Bar iron	22,249	869,519	19,380	796,631
Steel bars or rods, other than wire rods	9,300	608,144	17,802	929,915
Steel wire rods	24,613	831,067	22,449	713,718
Iron rails	211	4,639	181	8,808
Steel rails	67,455	1,902,396	30,656	937,779
Billets, ingots, and blooms	2,409	74,938	5,445	141,924
Hoop, band, and scroll	1,674	82,322	2,141	101,839
Iron sheets and plates	3,434	229,887	4,782	273,618
Steel sheets and plates	14,866	725,547	13,312	657,713
Tinplates and terne plates	1,566	143,691	292	28,481
Structural iron and steel	53,859	2,828,460	30,641	1,788,556
Wire	97,843	5,140,702	108,521	5,528,726
Cut nails and spikes	7,198	339,227	8,890	424,985
Wire nails and spikes	26,580	1,181,140	31,453	1,410,105
All other, including tacks	2,244	275,628	2,321	288,395
Car-wheels No.	21,714	141,969	18,966	136,569
Castings, not elsewhere specified	....	1,685,660	....	1,765,901
Cutlery	....	282,454	....	389,837
Fire-arms	....	976,967	....	1,206,951
Cash registers No.	14,018	1,220,791	20,260	1,825,503
Locks, hinges, etc	....	7,044,375	....	6,986,357
Saws	....	345,895	....	495,729
Tools, not elsewhere specified	....	3,930,495	....	4,658,972
Electrical machinery	....	5,937,643	....	5,104,502
Laundry machinery	....	519,065	....	552,291
Metal-working machinery	....	2,863,709	....	3,316,088
Printing presses, and parts of	....	843,613	....	1,143,122
Pumps and pumping machinery	....	2,516,300	....	2,729,288
Sewing machines	....	4,606,794	....	5,340,474
Shoemaking machinery	....	788,377	....	834,995
Fire engines No.	11	23,608	8	16,657
Locomotive engines "	368	3,966,007	287	3,099,521
Stationary engines "	1,280	672,957	1,730	714,508
Parts of engines and boilers	....	2,432,098	....	2,273,834
Typew'g machines, and parts of	....	3,575,909	....	4,537,396
Wood-working machinery*	....	....	....	359,338
All other machinery	....	20,930,519	....	20,068,810
Pipes and fittings	....	5,107,183	....	5,919,340
Safes No.	2,950	162,043	3,740	209,544
Scales and balances	....	506,877	....	762,305
Stoves, ranges, and parts of	....	868,695	....	981,475
All other manufactures	....	10,052,766	....	9,073,059
Total	372,399	$97,892,036	326,679	$99,035,865
Agricult. implements, additional	....	$17,981,597	....	$22,951,805
Iron ore Gross tons.	88,445	294,168	80,611	255,728

*Included in "all other machinery, etc.," prior to July 1, 1903.

Imports for Consumption of Ferro-Manganese, Spiegeleisen and Ferro-Silicon. — The following statistics of imports of ferro-manganese, spiegeleisen and ferro-silicon which were entered for consumption in the calendar years 1901, 1902 and 1903, were obtained from the Bureau of Statistics of the Department of Commerce and Labor. These imports are included in the statistics of imports of pig iron, spiegeleisen, ferro-manganese and ferro-silicon given in the preceding table:

Calendar years	1901		1902		1903	
Articles	Gross tons	Values	Gross tons	Values	Gross tons	Values
Ferro-manganese	20,751	$870,828	50,388	$1,818,036	41,518	$1,699,666
Spiegeleisen	26,827	677,246	62,813	1,473,853	122,016	2,709,317
Ferro-silicon	822	21,224	15,944	362,110	14,880	379,900

Productions of Iron Ore in 1902 and 1903. — The following table, compiled from statistics obtained by John Birkinbine for the United States Geological Survey, gives the production of iron ore in 1902 and 1903 by states, in gross tons.

States—Gross tons.	Production in 1902.	Production in 1903.
Minnesota	15,137,650	15,371,396
Michigan	11,135,215	10,600,330
Alabama	3,574,474	3,684,960
Tennessee	874,542	852,704
Virginia and West Virginia	987,958	801,161
Wisconsin	783,996	675,053
Pennsylvania	822,932	644,599
New York	555,321	540,460
New Jersey	441,879	484,796
Georgia	364,890	443,452
North Carolina		75,252
Montana, Nevada, New Mexico, Utah, and Wyoming	362,034	392,242
Colorado	293,297	252,909
Missouri	66,308	63,380
Texas	6,516	34,050
Kentucky	71,006	32,227
Connecticut, Massachusetts, and Vermont	29,093	30,729
Ohio	22,657	29,688
Maryland	24,367	9,920
Total	35,554,135	35,019,308

Lake Superior Iron Ore Shipments. — The following tables give the shipments in gross tons of Lake Superior iron ore in the last four years by ranges and by ports and all-rail. The figures include all shipments to local furnaces:

Ranges — Gross tons	1900	1901	1902	1903
Marquette Range	3,457,522	3,245,346	3,868,025	3,040,245
Menominee Range	3,261,221	3,619,083	4,612,509	3,749,567
Gogebic Range	2,875,295	2,938,155	3,663,484	2,912,912
Vermilion Range.....	1,655,820	1,786,063	2,084,263	1,676,699
Mesabi Range	7,809,535	9,004,890	13,342,840	12,892,542
Iron Ridge Mine......	....	....	....	17,913
Total............	19,059,393	20,593,537	27,571,121	24,289,878

Ports — Gross tons	1900	1901	1902	1903
Escanaba	3,436,734	4,022,668	5,413,704	4,277,561
Marquette............	2,661,861	2,354,284	2,595,010	2,007,346
Ashland	2,633,687	2,886,252	3,553,919	2,823,119
Two Harbors.........	4,007,294	5,018,197	5,605,185	5,120,656
Gladstone	418,854	117,089	92,375	85,816
Superior	1,522,899	2,321,077	4,180,568	3,978,579
Duluth	3,888,986	3,437,955	5,598,408	5,356,473
All-rail	489,078	436,015	531,952	640,328
Total............	19,059,393	20,593,537	27,571,121	24,289,878

The Marquette range is wholly in Michigan, the Menominee and Gogebic ranges are partly in Michigan and partly in Wisconsin, and the Vermilion and Mesabi ranges are in Minnesota.

Imports of Iron Ore in 1901, 1902 and 1903 by Countries. — The following table, which gives the countries from which iron ore was imported into the United States during the calendar years 1901, 1902, and 1903, was obtained from the Bureau of Statistics of the Department of Commerce and Labor:

Countries.	1901.		1902.		1903.	
	Tons.	Values.	Tons.	Values.	Tons.	Values.
Cuba	526,583	$705,086	696,375	$1,576,617	613,585	$1,501,480
Spain	180,810	399,364	153,527	338,261	94,720	196,139
French Africa	....	....	19,167	35,707	7,830	14,586
Greece	12,950	42,896	....	....	....	....
Newfoundland*	79,360	79,360	81,920	81,918	86,730	86,680
United Kingdom	490	15,939	1,269	17,882	6,843	31,868
British Columbia	2,875	4,313	5,661	9,312	525	789
Germany	400	3,415	361	3,478	207	1,820
Quebec, Ont., etc.	163,383	408,431	203,824	509,711	169,681	424,340
Belgium	....	....	500	4,850	300	2,964
France	....	....	2,866	5,341	....	....
Other countries	99	469	....	....	19	342
Total	966,950	$1,659,273	1,165,470	$2,583,077	980,440	$2,261,008

* Newfoundland only for 1901 and 1903; Newfoundland and Labrador for 1902.

Imports of Manganese Ore Since 1889. — The following table was obtained from the same source:

Years	Gross tons	Years	Gross tons	Years	Gross tons
1889	4,286	1894	44,655	1899	188,349
1890	34,154	1895	86,111	1900	256,252
1891	28,825	1896	31,489	1901	165,722
1892	58,572	1897	119,961	1902	235,576
1893	68,113	1898	114,885	1903	146,056

Production of Pig Iron by Grades. — The following table gives the total production of pig iron in the United States in 1901, 1902 and 1903, by grades, in gross tons:

Grades — Gross tons	1901	1902	1903
Bessemer and low-phosphorus pig iron	9,596,793	10,393,168	9,989,908
Basic pig iron made with mineral fuel	1,448,850	2,038,590	2,040,726
Forge pig iron	639,454	833,093	783,016
Foundry and high silicon pig iron	3,548,718	3,851,276	4,409,023
Malleable Bessemer pig iron	256,532	311,458	473,781
White and mottled and miscellaneous	87,964	172,085	120,137
Spiegeleisen	231,822	168,408	156,700
Ferro-manganese	59,639	44,573	35,961
Direct castings	8,582	8,656	....
Total	15,878,354	17,821,307	18,009,252

Production of Pig Iron According to Fuel. — The production of pig iron in 1903, classified according to the fuel used, was as follows, compared with the four preceding years:

Fuel used — Gross tons	1899	1900	1901	1902	1903
Bituminous, chiefly coke	11,736,385	11,727,712	13,782,386	16,315,891	15,592,221
Anthracite and coke ...	1,558,521	1,636,366	1,668,808	1,096,040	1,864,199
Anthracite alone	41,031	40,682	43,719	19,207	47,148
Charcoal	284,766	339,874	360,147	378,504	504,757
Charcoal and coke.....	....	44,608	23,294	11,665	927
Total	13,620,703	13,789,242	15,878,354	17,821,307	18,009,252

Production of Spiegeleisen and Ferro-Manganese Since 1893 — (Included in total production of pig iron):

Years	Gross tons	Years	Gross tons	Years	Gross tons
1893	81,118	1897	173,695	1901	291,461
1894	120,180	1898	213,769	1902	212,981
1895	171,724	1899	219,768	1903	192,661
1896	131,940	1900	255,977	....	....

Number of Completed Furnaces. — The whole number of completed furnaces in the United States at the close of 1903 was 425, against 412 at the close of 1902 and 406 at the close of 1901. The following table shows t e number of completed furnaces at the end of each year since 1898, not counting abandoned furnaces in any year:

Fuel used	1898	1899	1900	1901	1902	1903
Bituminous coal and coke	242	235	240	257	272	288
Anthracite and anth. and coke ...	94	99	94	90	81	77
Charcoal and charcoal and coke ...	78	80	72	59	59	60
Total	414	414	406	406	412	425

Number of Furnaces in Blast. — The whole number of furnaces which were in blast at the close of 1903 was 182, against 307 at the close of 1902 and 266 at the close of 1901. The

following classified table shows the number of furnaces in blast at the close of each year since 1898:

Fuel used	1898	1899	1900	1901	1902	1903
Bituminous coal and coke	152	191	155	188	222	120
Anthracite and anth. and coke ...	30	68	45	54	52	29
Charcoal and charcoal and coke ...	20	30	32	24	33	33
Total	202	289	232	266	307	182

The number of furnaces out of blast at the close of 1903 was 243. Some of these furnaces were only temporarily banked.

Production of Bessemer Steel. — The total production of Bessemer steel ingots and castings in the United States in the last five years was as follows:

	1899	1900	1901	1902	1903
Gross Tons,	7,586,354	6,684,770	8,713,302	9,138,363	8,592,829

Small Converters. — There were no Clapp-Griffiths works in operation in 1903 and only two Robert-Bessemer plants were active. Eight Tropenas plants were at work, as compared with five in 1902. In addition one plant made steel by the Bookwalter process and one plant on the Pacific coast made a small quantity of steel in a special surface-blown converter. One plant also made steel by the Evans-Wills process. All these works produced steel castings only.

Since the close of 1903 the following plants have installed or are now installing Tropenas or other "little Bessemer" converters: Watertown Arsenal, Watertown, Mass., one 2-gross-ton Tropenas converter; Providence Steel Casting Company, Providence, R. I., two 2-gross-ton Tropenas converters; Southern Steel Works, Chattanooga, Tenn., one 2-gross-ton Tropenas converter; and the Milwaukee Steel Foundry Company, Milwaukee, Wis., one 1-gross-ton special steel converter.

Production of Open-Hearth Steel. — The total production of open-hearth steel ingots and direct castings in the United States for the last six years was as follows:

	1898	1899	1900	1901	1902	1903
Gross Tons,	2,230,292	2,947,316	3,398,135	4,656,309	5,687,729	5,829,911

Production of Acid and Basic Open-Hearth Steel. — The production of acid and basic open-hearth steel in 1902 and 1903 was as follows:

	1902	1903
Acid	1,191,196	1,094,998
Basic	4,496,533	4,734,913
Total	5,687,729	5,829,911

Production of Open-Hearth Steel Castings. — The growth of the open-hearth steel casting industry in this country has been very rapid within the last six years, as is shown by the following table, the increase from 1898 to 1903 amounting to 279,761 gross tons, or almost 232 per cent. The greatest growth has been in Pennsylvania, the increase in that state alone from 1898 to 1903 amounting to 134,751 gross tons, or over 285 per cent. The production of open-hearth steel castings was first separately ascertained by the American Iron and Steel Association in 1898.

	1898	1899	1900	1901	1902	1903
Gross Tons,	120,587	169,729	177,491	301,622	367,879	400,348

Production of Crucible Steel Since 1893. —

Years	Gross tons	Years	Gross tons	Years	Gross tons
1893	63,613	1897	69,589	1901	98,513
1894	51,702	1898	89,747	1902	112,772
1895	67,666	1899	101,213	1903	102,434
1896	60,689	1900	100,562	......	......

Production of Miscellaneous Steel. — The production of steel in the United States in 1903 by various minor processes amounted to 9,804 gross tons, against 8,386 tons in 1902, 5,471 tons in 1901, 4,862 tons in 1900, 4,974 tons in 1899, 3,801 tons in 1898, 3,012 tons in 1897, 2,394 tons in 1896, 858 tons in 1895, 4,081 tons in 1894, and 2,806 tons in 1893. Blister, puddled, and "patented" steel, including "patented" steel castings, are included in these figures.

Production of All Kinds of Steel. — The production of all kinds of steel ingots and castings in the United States in the fourteen years from 1890 to 1903 inclusive is as follows:

Years — Gross tons	Bessemer	Open-hearth	Crucible	Miscellaneous	Total. Ingots and Castings
1890	3,688,871	513,232	71,175	3,793	4,277,071
1891	3,247,417	579,753	72,586	4,484	3,904,240
1892	4,168,435	669,889	84,709	4,548	4,927,581
1893	3,215,686	737,890	63,613	2,806	4,019,995
1894	3,571,313	784,936	51,702	4,081	4,412,032
1895	4,909,128	1,137,182	67,666	858	6,114,834
1896	3,919,906	1,298,700	60,689	2,394	5,281,689
1897	5,475,315	1,608,671	69,959	3,012	7,156,957
1898	6,609,017	2,230,292	89,747	3,801	8,932,857
1899	7,586,354	2,947,316	101,213	4,974	10,639,857
1900	6,684,770	3,398,135	100,562	4,862	10,188,329
1901	8,713,302	4,656,309	98,513	5,471	13,473,595
1902	9,138,363	5,687,729	112,772	8,386	14,947,250
1903	8,592,829	5,829,911	102,434	9,804	14,534,978

Production of All Kinds of Steel Castings Since 1898. —

	1898	1899	1900	1901	1902	1903
Gross Tons,	131,937	181,112	192,803	317,570	390,935	430,265

Production of Iron Blooms and Billets. — The production of blooms and billets from the ore since 1892 is shown in the following table:

Years	Gross tons	Years	Gross tons	Years	Gross tons
1892	2,182	1896	1,346	1900	4,292
1893	864	1897	1,455	1901	2,310
1894	40	1898	1,767	1902	None
1895	40	1899	3,142	1903	None

All the ore blooms produced since 1897 were made by the Chateaugay Ore and Iron Company, of Plattsburgh, N. Y., at its Standish Works, which were, however, idle in 1902 and 1903.

The production of iron blooms produced in forges from pig iron and scrap since 1896 and which were for sale and not for the consumption of the makers, is given below:

Years	Gross tons	Years	Gross tons	Years	Gross tons
1896	6,494	1899	9,932	1902	12,002
1897	7,159	1900	8,655	1903	9,940
1898	6,345	1901	8,237	......	......

SUMMARY OF STATISTICS FOR 1902 AND 1903.

Subjects—Calendar years.	1902.	1903.
Production of Iron Ore, gross tons	35,554,135	35,019,308
Imports of Iron Ore, gross tons	1,165,470	980,440
Production of Bituminous Coal, gross tons	232,336,468	252,454,775
Production of Pennsylvania Anthracite, gross tons	36,940,710	66,613,454
Production of all kinds of Coal, gross tons	269,277,178	319,068,229
Shipments of Pennsylvania Anthracite, gross tons	31,200,890	59,362,831
Imports of Coal, gross tons	2,551,381	3,446,402
Exports of Coal, gross tons	6,126,946	8,312,098
Production of Coke, net tons	25,401,730	25,262,360
Production of Pig Iron, gross tons	17,821,307	18,009,252
Production of Spiegeleisen and Ferro-manganese, included in Pig Iron, gross tons	212,981	192,661
Production of Bessemer Steel, gross tons	9,138,363	8,592,829
Production of Open-hearth Steel, gross tons	5,687,729	5,829,911
Production of Crucible Steel, gross tons	112,772	102,434
Production of Blister and Patented Steel, gross tons	8,386	9,804
Production of all kinds of Steel, gross tons	14,947,250	14,534,978
Production of Open-hearth Steel Castings, gross tons	367,879	400,348
Production of all kinds of Steel Castings, gross tons	390,935	430,265
Production of Bessemer Steel Rails, gross tons	2,935,392	2,946,756
Production of Open-hearth Steel Rails, gross tons	6,029	45,054
Production of Iron Rails, gross tons	6,512	667
Production of all kinds of Rails, gross tons	2,947,933	2,992,477
Production of Structural Shapes, gross tons	1,300,326	1,095,813
Production of Iron and Steel Wire Rods, gross tons.	1,574,293	1,503,455
Production of Plate and Sheet Iron and Steel, except Nail Plate, gross tons	2,665,409	2,599,665
Production of Iron and Steel Cut Nails and Cut Spikes, kegs of 100 pounds	1,633,762	1,435,893
Production of Iron and Steel Wire Nails, kegs of 100 pounds	10,982,246	9,631,661
Production of Bar, Bolt, Hoop, Skelp, Rolled Axles, Rolled Armor Plate, etc., gross tons	5,383,219	4,952,185
Production of all Rolled Iron and Steel, including Cut Nails and excluding Rails, gross tons	10,996,183	10,215,220
Production of all Rolled Iron and Steel, including both Cut Nails and Rails, gross tons	13,944,116	13,207,697
Production of Tinplates and Terne Plates, gross tons.	360,000	480,000
Production of Ore, Pig, and Scrap Blooms for sale, gross tons	12,002	9,940
Value of Imports of Iron and Steel	\$41,468,826	\$41,255,864
Value of Exports of Iron and Steel	\$97,892,036	\$99,035,865
Miles of New Railroad built (revised figures)	5,063	4,715
Immigrants in the year ended December 31	739,289	937,371

RECENT PUBLICATIONS

Forge Practice, by John Lord Bacon, instructor in forge work, Lewis Institute, Chicago. 257 5 × 7-in. pages; 272 illustrations. John Wiley and Sons. New York. 1904. Price, $1.50. — This work includes chapters on the following subjects: Description of Forge and Tools, Welding, Calculation of Stock for Bent Shapes, Upsetting, Drawing Out and Bending, Simple Forged Work, Making of General Forgings, Steam Hammer Work, Duplicate Work, Metallurgy of Iron and Steel, Tool Steel Work, Tool Forging and Tempering. In recent years many books have been published dealing with the shop treatment of steel, and it is fair to say that in most cases each new book had some merits of its own justifying its introduction in a field already well occupied. The special merits of the book we have before us are to be found in the clear and practical description it gives of the treatment of steel at the forge and anvil. The numerous original figures which were prepared to illustrate the text are very good. The chapter devoted to the Metallurgy of Iron and Steel, while on the whole quite satisfactory, contains a few statements open to criticism. On page 158 the author refers to machine steel as containing from 0.02 to 0.60 per cent of carbon. We doubt that steel containing but 0.02 per cent of carbon could be found on the market. Five hundredths per cent carbon would be a more likely lower limit. On page 160 the author describing the blast-furnace process writes that the ore " as it melts, is deoxidized," while, of course, the reduction of the ore takes place chiefly in the upper part of the furnace, long before the melting point of the iron or of the slag is reached. On page 167 it is stated that " open-hearth steel is made by melting together pig iron, cast iron and scrap iron and steel and removing the carbon by the action of an oxidizing flame of burning gas." The distinction which the author makes between pig iron and cast iron is not clear and he does not mention the use of iron ore in the process. Again, in the open-

hearth process as now generally carried on, the carbon is oxidized chiefly through the oxygen of iron oxide added to the bath, and only to a relatively small extent by the flame. The use of cemented or blister steel in the production of crucible steel is not mentioned in the book. On page 158 it is stated that machine steel contains from 0.02 to 0.60 per cent of carbon, and on page 173 the author writes that these mild steels will not harden to any extent, whereas a steel containing over, say, 0.30 per cent carbon, becomes intensely hard after rapid cooling. It is very satisfactory to read the author's statement on page 165 that the fibrous appearance of wrought iron is due to the presence of elongated particles of slag and not to a fibrous condition of the iron itself, seeing that so many modern and otherwise authoritative writers still describe wrought iron as having a fibrous structure. The book may be highly commended to steel workers. It is attractively printed and bound.

Foundry Practice, A Treatise of Molding and Casting in Their Various Details, by James M. Tate and Melvin O. Stone. 235 5 × 7½-in. pages; 111 illustrations. H. W. Wilson Company. Minneapolis. 1904. Price, $1.50. This book was prepared primarily for the use of students in the College of Engineering of the University of Minnesota. The treatment of the subject is confined almost exclusively to the mechanical side of foundry operations, and especially to molding, the metallurgy of the foundry being hardly alluded to. The mixing of cupola charges for instance is dismissed with the following instructions: "In order to produce a soft iron for machinery castings, mix one part of soft foundry pig iron with four parts of machinery scrap iron." On page 116 the authors, referring to the melting of pig iron in reverberatory furnaces, say that "when iron is in a molten state, the presence of oxygen will affect the carbon in the iron and burn out the graphitic carbon, making it harder and more brittle," whereas molten cast iron does not contain any graphitic carbon; the iron becomes harder because the amount of total carbon is generally lowered in the reverberatory furnace, which, in turn, means the formation of a smaller amount of graphitic carbon when the castings made with that iron solidify. On page 175 the authors write that in mixtures for chill castings "the combined or hardening carbon should rarely exceed 0.6

per cent," apparently considering these two terms synonymous. The same use of the words "hardening" and "combined" is repeated on page 177. In their description of the malleableizing of cast iron the authors lay much stress upon the oxidizing action of the packing material, whereas the change in the carbon condition upon which the operation depends is quite independent of the nature of the packing material and, indeed, takes place as readily without any packing at all. The book includes a chapter on brass molding and a glossary of foundry terms. The authors' description of purely mechanical operations is methodical and generally satisfactory.

High Temperature Measurements, by H. Le Chatelier and O. Boudouard. Authorized translation and additions by G. K. Burgess. Second edition revised and enlarged. 341 5 × 7-in. pages; 79 illustrations. John Wiley and Sons. New York. 1904. — The measurement of high temperatures has never received more attention than at the present day. In most industries scientific methods are more and more replacing rule-of-thumb operations, and this calls, when heat takes a part in the process, for the use and understanding of pyrometers. In no other manufacture is this more true than in metallurgical operations, and especially in those operations which deal with the production and further treatment of iron and steel. This second edition of the translation of Le Chatelier and Boudouard's authoritative book is certain to be widely welcome. The translator writes that because of recent advance in pyrometry it has been necessary to completely revise the work, which was done at the request of Professor Le Chatelier. The original text has been left intact as far as possible and the results of recent work inserted in the appropriate chapters, all of which have been so modified. The book is divided into fourteen chapters as follows: "Normal Scale of Temperature," "Normal Thermometer," "Gas Thermometer," "Calorimetric Pyrometer," "Electric Resistance Pyrometer," "Thermoelectric Pyrometer," "Laws of Radiation" (a new chapter), "Heat Radiation Pyrometer," "Optical Pyrometer," "Expansion and Contraction Pyrometers," "Fusing Point," "Dilation and Transpiration Pyrometer," "Recording Pyrometer," "Standardization of Pyrometers," "Conclusion." The name of the publishers is a

guarantee that the typography and binding leave nothing to be desired.

Statistics of the American and Foreign Iron Trades for 1903. 94 6 × 9-in. pages; paper covers. The American Iron and Steel Association. Philadelphia. 1904. Price, $3.00. — These statistics, which were as usual compiled by James M. Swank, general manager of the American Iron and Steel Association, were presented to the members, October 31, 1904. This is the thirty-second annual report of Mr. Swank, the first one having been issued in 1873. The present report occupies 94 pages and will be found to be one of the most comprehensive ones ever issued by the Association.

In addition to the usual statistics of production and prices of all leading iron and steel products, iron ore, coal and coke and statistics of imports and exports, it contains statistics of all the products mentioned in greater detail than has heretofore characterized these annual reports, while many statistical tables of a historical character that are frequently called for by correspondents have been reproduced and brought down to the present time. Statistics of the operations of the United States Steel Corporation in 1902 and 1903, compared with the operations of the independent iron and steel companies in these years, are given in detail. Statistics of the Canadian iron and steel industries are given in full for 1903. Tables giving the world's production of iron ore, coal, pig iron and steel in the latest years for which statistics have been received will be found at the end of the report.

The accuracy, exhaustiveness and general excellence of Mr. Swank's statistical work is deserving of the highest praise and cannot fail of appreciation by all those interested in the iron and steel industry. In the present issue of the *Iron and Steel Magazine* we reproduce many statistical tables and other extracts from this valuable publication.

The Study of the Atom, by F. P. Venable, University of North Carolina. 290 5 × 8-in. pages. The Chemical Publishing Company. Easton, Pa. — The interest and importance of a book of this character is well expressed by the author in the following words which we quote from his introduction:

"The purpose of this work is to trace the atomic theory of chemistry from its earliest conception to the present day. This forms the foundation of all chemical theory and has been offered as the best explanation of the constitution of matter and of the universe. This theory has had a longer life than any other philosophical or scientific conception, and has to-day more nearly its ancient form. It has lived through bitter attack, dialectic strife and even persecution, and can number its martyrs. It has called to its service the master minds of the world and the greatest ingenuity in experiment and in logic. It is not to be presumed that such a conception can be dismissed in a few slighting sentences or overturned by one or two crude hypotheses."

The subject is divided into eight chapters as follows: "Ancient View as to the Nature of Matter, from the Greek Philosophers to Dalton," "The Atomic Theory of Chemistry," "The Relative Weights of the Atoms," "The Periodic or Natural System," "Affinity," "the Atomic Binding Force," "Valence," "Molecules and the Constitution of Matter." The author deals with the history of the atomic theory more exhaustively, we think, than was ever done before, and his book is certainly one of the most notable contributions to this important subject since the publication of Wurtz' "Atomic Theory." It is to be regretted that a better paper and a better binding were not selected for so interesting a book.

Manual of the Chemical Analysis of Rocks, by Henry S. Washington. 183 6 × 9-in. pages. John Wiley and Sons. New York. 1904. Price, $2.00. — With the exception of Hillebrand's well-known treatise on the "Analysis of Rocks," there exists no other book devoted to this subject. Hillebrand's treatment, moreover, presupposes a rather advanced knowledge of analytical chemistry on the part of the reader, while the book we have before us is written in a more elementary manner and will, therefore, appeal to a greater number. The following is extracted from the author's preface: "There is an increasing number of geologists, petrologists, chemists and others who are desirous of making chemical analysis of rocks, but who have had little or no experience in the subject, except that gained in the ordinary course of quantitative analysis, in which the study of silicates is usally confined to the examination of a feldspar or

some such simple mineral. It is for the benefit of this class of students that the present book is written." The book is well printed and attractively and substantially bound.

Quantitative Chemical Analysis by Electrolysis, by Prof. Alexander Classen; translated from German into English by Bertram B. Boltwood. 315 6 × 9-in. pages; 102 illustrations. John Wiley and Sons. New York. 1903. Price, $3.00. — The fourth German edition of this well-known book appeared in 1897, and in the present translation much matter is included which has been published since, chiefly in the author's work on "Ausgewählte Methoden der Analytischen Chemie," written in 1902. The book is divided into three parts. Part one is subdivided into two sections, the first one being devoted to theoretical considerations concerning the nature of solution, electrolytes, migration of ions, etc.; the second describing electro-analytical methods for the determination of various metals. Part second deals with the quantitative determination of metals, the determination of nitric acid in nitrates, the determination of the halogens, etc. Part third is devoted to applied examples of electro-chemical analysis and to reagents. The book is an authoritative one which cannot fail to be welcome by all students of analytical chemistry. Like all the publications of John Wiley and Sons it is well printed on good paper and neatly and substantially bound.

Notes on Assaying and Metallurgical Laboratory Experiments, by Richard W. Lodge, assistant professor of mining and metallurgy, Massachusetts Institute of Technology. 287 6 × 9-in. pages; illustrated. John Wiley and Sons. New York. 1904. Price, $3.00. — Notwithstanding the already profuse existing literature on assaying and related subjects, this new contribution will undoubtedly be appreciated by students and assayers, because of the clearness and method of the treatment and of the experience of the author. The subject is taken up in the following order: "Apparatus, Reagents and Materials," "Sampling," "Assay of Ores for Silver," "Assay of Ores for Gold," "Assay of Ores for Lead," "Bullion," "Assay of Ores for Copper and Tin," "Platinum and the Platinum Group." Sixty pages are devoted to a description of some metallurgical laboratory

experiments conducted by students in the fourth year of the Mining Course at the Massachusetts Institute of Technology. They include tests in calcining, roasting, chlorination of gold ore, cyaniding treatment of roasted gold ores by means of bromide, experimental treatment of gold-bearing ores, melting, refining, toughening, pouring and casting bullion, retorting and cleaning mercury, muffle chloridizing roast of silver ores, pan amalgamation, etc. The typography, paper and binding are excellent in every respect.

Transactions of the American Electrochemical Society, Vol. V, 1904. 284 $5\frac{1}{2} \times 9$-in. pages. The American Electrochemical Society. Philadelphia. 1904. Price, $3.00. To libraries, societies and journals, $2.00. — This volume contains the proceedings of the fifth general meeting of the society held at Washington in April, 1904, and includes over 20 papers read at that meeting. The secretary reported a membership of 661, being an increase of 163 over the membership in April, 1903. The photograph of the president, Henry S. Carhart, is reproduced as a frontispiece.

Tonnage Conversion Tables, by William J. Mann. 155 $4\frac{1}{2} \times 6$-in. pages. Published by the author. Bethlehem, Pa. 1904. Price, $2.00. — These useful tables have been arranged for the convenience of converting pounds into their equivalent in tons and fractional parts of a ton, and vice versa. They will appeal to all those who have to deal with such conversion and especially to weighmasters, billing clerks, freight clerks, etc.

Manufacturing Cost, by H. L. Hall. 192 5×7-in. pages; illustrated. The Book-Keeper Publishing Company, Ltd. Detroit, Mich. 1904. Price, $3.00. — This book deals with cost accounting, its principles and their application, and covers the entire field of a manufacturing establishment from the purchasing agent to the salesman. It contains illustrations of many special forms, charts and devices.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

773,450. PROCESS OF MAKING ALLOYS. — Robert S. Anderson, Seattle, Wash., assignor of three fourths to Walter F. Horner, Willis C. Meeker and Hiram U. Woodin. A process of producing an alloy which consists in mixing copper and tin and heating the same until they are brought into a molten mass and then adding copper sulphate and finally adding aluminum.

773,529. METHOD OF CARBON ANALYSIS. — George O. Seward, Holcombs Rock, Va., assignor to Eimer & Amend, New York, N. Y. A method of determining the amount of carbon contained in a substance consisting in mixing the said substance with an oxidizing agent, and confining said mixture, causing an electric arc to raise a portion of the mixture to a kindling temperature, causing carbon dioxide formed by the reaction to pass through potassium hydroxide or other absorbing agent, thereby collecting the said carbon dioxide, covering the residual mixture with diluted sulphuric acid, boiling the said acid, and then causing purified air to pass over the surface of and through the sulphuric acid containing the said residual mixture, and over the said potassium hydroxide and weighing the said potassium hydroxide.

773,548. FAN OR BLOWER. — William A. Cross, Chicago, Ill. A fan blower comprising in combination a series of fan-blades having two series of inner attaching shanks arranged in separate relation, a central carrying hub provided with facets at one end for the tangential attachment of one series of said shanks, and with tangential sockets at the other end for the tangential attachment of the other series of said shanks, and attaching bolts for securing said shanks in place.

773,634. FURNACE-CHARGING APPARATUS. — Samuel Forter, Pittsburg, Pa., assignor to Forter-Miller Engineering Company. In a furnace-charging apparatus, a truck having a movable body, a reciprocating rod to move said body, a sleeve on the rod, a nut on said rod capable of working against said sleeve so as to move the rod in the sleeve, a bell-crank lever having one arm connected to the sleeve and the other arm provided with means for attachment to a hoisting device.

773,663 and 773,665. SAND-BLAST APPARATUS. — Jeremiah E. Mathewson, Broadheath, England. In a sand-blast apparatus for cleaning castings the combination with a sand-blast machine and a chamber in which the castings are cleaned, having collecting-hoppers and a suction pipe, of a cyclone-separator for separating the air and the finer dust from

the cutting-sand, and an air-sieving device arranged to receive the residual sand from said separator and to complete the separation of the cutting-sand from the unusable fine sand and dust.

773,684. Recording Pyrometer. — Frank N. Speller, McKeesport, Pa. In a heat-measuring device, the combination of a chamber adapted to be subjected to the heat to be measured, a device for producing suction therein, means controlled by the pressure in the heated chamber for regulating the suction device, and a pressure-indicating device connected to the suction device.

773,809. Coke-Oven. — George S. Ramsay, St. Marys, Pa. A coke-oven having a stack, and provided with a main bottom flue communicating at one end with the stack, front and rear upstanding flues communicating at their upper ends with the interior of the oven, and the independent front and rear bottom flues connecting the upstanding flues with the main flue, the flues on each side of the main bottom flue being independent of the flues on the opposite side and also independent of each other.

773,992. Process of Manufacturing Peat Fuel. — Carl F. Schlickeysen, Steglitz, Germany. The process for the manufacture of peat fuel, which consists in mixing comminuted wet native peat with coarsely subdivided dry matter, and forming into briquettes.

774,035. Guide for Rolling-Mills. — William Bunton, Munhall, Pa. The combination with the housings, the rolls and the guides supported from the housings adjacent to the passes between the rolls, of brackets carried by the housings, a plate adjustably supported on said brackets, auxiliary or supplemental guides adjustably supported on said plate, and means for opening or closing said auxiliary or supplemental guides.

774,069. Method of Treating Sheet Iron or Steel. — Harry H. Goodsell, Leechburg, Pa. A method of treating sheet iron or steel, which consists in subjecting said sheet iron or steel to the action of steam at a high temperature, gradually lowering the temperature of said iron or steel while the same is in contact with said steam, submerging said iron or steel in boiling water, and finally drying said iron or steel.

774,087. Automatic Mechanism for use in Step-by-Step Rolling of Metal Tubes. — Richard Laybourne, Charles W. E. Marsh and Benjamin Price, Newport, England. In apparatus for rolling or swaging metal tubes from hollow ingots step by step, and having a feed-screw and mandrel adapted to intermittently advance and rotate the work-piece on said mandrel, the combination with such feed-screw and mandrel of a yielding clutch shiftably secured to and surrounding said feed-screw and adapted to be intermittently and automatically thrown out of gear with said feed-screw each time the rolls grip the work-piece and thereby prevent the rotation and advance of the feed-screw and mandrel while the work-piece is thus gripped, means for automatically forcing the yielding part of said clutch into gear with a constantly rotating part of said clutch when the work-piece mandrel and feed-screw are liberated by the rolls, and means to constantly rotate said rotating clutch part for

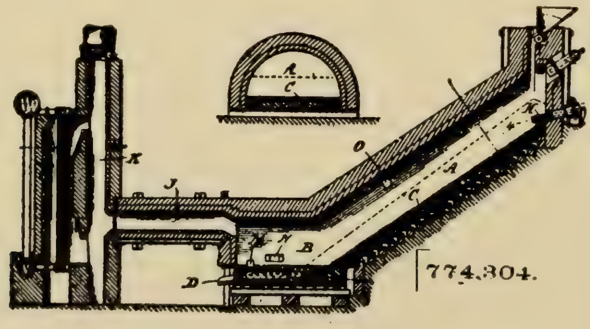
the purpose of advancing and turning the feed-screw mandrel and work-piece thereon for a suitable distance when the latter is released from the rolls to thereby expose a fresh part of the work-piece to the action of the rolls.

774,167. Direct Casting and Hardening of Metal for Armor Plate, etc. — Willis E. Everette, Tacoma, Wash. A method of direct casting and hardening of metal for armor-plate and other articles, which consists in melting a charge of metal or metallic ore by a flux, consisting of the cyanide of an alkali, and injecting into the molten mass a quantity of molten cyanide of an alkali, mixed with from 1 to 10 per cent of pulverized sulphide of molybdenum, from 0.5 to 5 per cent of metallic manganese, from 1 to 10 per cent of chromium, and drawing off and cooling the molten mass by a spray of liquid carbonic acid.

774,212. Testing Machine. — William J. Tretch, Philadelphia, Pa., assignor to Frederick A. Riehle, Philadelphia, Pa. In a testing machine, a shot receptacle having an emission-aperture, means within said receptacle for closing said aperture, a stationary portion below said receptacle, and means rising from said stationary portion and normally disengaged from said closing means, but adapted to engage with said closing means to positively hold the same when the shot-receptacle is moved upward by reason of the breaking of a specimen.

774,287. Bloom-Shears. — Clarence L. Taylor, Alliance, Ohio, assignor to the Morgan Engineering Company, Alliance, Ohio. In bloom-shears, the combination with a frame, a movable cross-head carrying the lower cutter, and an upper movable cross-head carrying the upper cutter, of a cylinder and plunger carried by the upper cross-head and tie-rods connecting said plunger and lower cross-head.

774,304. Metallurgical Process. — Martin P. Boss, San Francisco, Cal. A method of producing steel direct from iron ore, which



774,304.

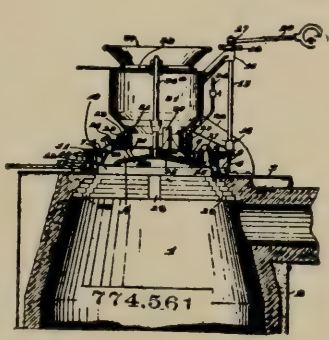
consists in subjecting the ore to the reducing action of a hydrocarbon flame, and at the same time to the combining action of a hydrocarbon vapor.

774,311. Manufacture of Lap-Weld-Pipes. — Rufus C. Crawford and George Baehr, McKeesport, Pa., assignors to National Tube Company, Pittsburg, Pa. A method of making lap-weld-tubing, which consists in charging in succession a series of bent-up skelp into a furnace

on to one zone of the hearth thereof, raising their edges to a welding heat, passing them in succession through welding rolls and over a mandrel, then, while still at a high heat, recharging the tubes in succession on to another zone of the same hearth and reheating the same, and then giving them in succession a second pass through welding-rolls and over a mandrel, whereby a continuous double-welding process is carried on.

774,337. METHOD OF MAKING LAP-WELD-TUBING. — Peter Patterson, McKeesport, Pa., assignor to National Tube Company, Pittsburg, Pa. A method of making lap-weld-tubing, which consists in charging in succession a series of bent-up skelp into a furnace on one side of the hearth thereof, gradually moving the same over toward the center of the furnace, withdrawing the same in succession from the furnace and passing them through welding-rolls and over a mandrel, recharging them in succession into the same furnace and on the opposite side of the hearth thereof, again gradually moving the same over toward the center of the furnace, and again withdrawing the same in succession from the furnace and giving them a second pass through welding-rolls and over a mandrel.

774,387. HOISTING APPARATUS FOR BLAST-FURNACES. — Harry Heffrin, Pittsburg, Pa., assignor to Thomas H. Martin, trustee, Pittsburg, Pa. A hoisting mechanism for blast-furnaces, having in combination a skipway, a constant-speed motor, a car movable along the skipway, and means for moving said car operated by said motor, and having a slower speed as the car approaches the ends of its travel than between intermediate points.



774,561. CHARGER FOR GAS-PRODUCERS. — Elbert H. Carroll, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. A fuel-feed for gas-producers, consisting of a stationary top plate, a fuel-supply reservoir and a rotary feed-casting interposed between the two, and provided with an opening eccentric to its axis of rotation, through which the fuel drops from the reservoir on to the top plate, and from which it is swept by the movement of the feed-casting.

774,788. CHARGING APPARATUS FOR BLAST-FURNACES. — Karl Schneider, Koblenz, Germany. The combination, with adjacent blast-furnaces, of apparatus adapted to supply both of said furnaces from a single hoist, said apparatus consisting of a combined charging-receptacle and conveyer receiving the charge of material from the hoist and normally occupying a position above the top of one of the furnaces, and a runway for said receptacle-conveyer leading to a corresponding position above the top of the other furnace.

774,795. ROLLING-MILL. — Ralph C. Stiefel, Ellwood City, Pa., assignor, by mesne assignments, to National Tube Company. In a rolling-mill, the combination with the rolls, of turning devices having roughened surfaces for engaging and positively rotating the billet about

its longitudinal axis, and means for positively reciprocating said turning devices transversely to the direction of movement of the billet independently of the rolls.

774,796. ROLLING-MILL. — Ralph C. Stiefel, Ellwood City, Pa., assignor, by mesne assignments, to National Tube Company. In a continuous tube-rolling mill, the combination of a plurality of pairs of rolls, a removable mandrel-bar between each pair separate from the mandrel-bar between any other pair, and removable supports for the rear ends of the mandrel-bars, means for supporting the mandrel-bars in position relatively to the rolls, and means for operating the said parts to pass the tubular billet successively through all the rolls and on to each of the mandrels.

774,958. MANUFACTURE OF STEEL. — Tolmie J. Tresidder, Sheffield, England. Steel containing iron and carbon, manganese, nickel and tungsten in about the following proportions: Carbon, 0.28 to 0.32 per cent; manganese, 0.25 to 0.30 per cent; nickel, 2.25 to 2.50 per cent; and tungsten, 0.28 to 0.32 per cent, the remainder being iron.

774,959. MANUFACTURE OF STEEL ARMOR-PLATE, ETC., WITH A HARDENED FACE. — Tolmie J. Tresidder, Sheffield, England. The manufacture of steel plates by first producing an ingot of steel composed of iron, carbon, manganese, nickel and tungsten, and forging, or rolling; then cementing, or supercarburizing, the face and cooling, and afterward restoring the fibrous character to the uncemented part.

774,973. TREATING SCRAP-STEEL AND RECARBURIZING SAME. — Herbert B. Atha, East Orange, N. J. A process of preparing scrap-steel for remelting in an open-hearth furnace, which consists in placing carbon in receptacles and mixing the receptacles with the scrap steel.

775,022. APPARATUS FOR REDUCING METAL BARS TO SHEETS IN PILE IN A HEATED STATE. — Thomas V. Allis, Bridgeport, Conn. In combination with roughing-rolls adapted to reduce bars in a heated state into plates, a roll-conveyer leading from the roughing-rolls to a heating-furnace and adapted to deliver the plates to said furnace at a plane above that of the roughing-rolls, a heating-furnace provided with a throat or inlet opening in alinement with the roll-conveyer, an inclined plate-support having vertical stops for automatically registering successive plates into a pile and an exit-door through which said pile may be removed.

775,026. MECHANICAL PUDDLING-FURNACE. — Walter B. Burrow, Norfolk, Va. In a stationary reverberatory mechanical puddling-furnace for making wrought iron, the combination of a wheeled or roller-supported oscillating and horizontally operated hearth, a concavity in the lining near the bed of the hearth, a projecting overhanging refractory rim or ledge over the said concave lining and the bed, the said rim extending entirely around the inside of the hearth, a lug or arm under the bottom of the hearth, and means for imparting a rocking motion to the arm or lug and the hearth in the direction of its length.

BENJAMIN TALBOT

SEE PAGE 175

The Iron and Steel Magazine

". . . . . . *Je veux au mond publier
d'une plume de fer sur un papier d'acier.*"

Vol. IX February, 1905 No. 2

SULPHIDES AND SILICATES OF MANGANESE IN STEEL *

By J. E. STEAD

Special Contributor to The Iron and Steel Magazine

IN 1885, Osmond & Werth † discovered by chemical analysis that the sulphur in steels which contain manganese exists as sulphide of manganese. They found that mercuric chloride was inactive upon the sulphide of manganese in steel, but, according to a well-known chemical action, it dissolved the iron. In this way the sulphide was isolated.

In 1888, Osmond described experiments which show that on the fractional solution of steel in hydrochloric acid, the insoluble part contains a less percentage of manganese and sulphur than is present in the fraction dissolved.‡

When chemist at the Gorton Steel Works, near Manchester, above thirty years ago, the sulphur in pig metals and steels

* Received December 26, 1904.

† "Théorie Cellulaire des propriétés de l'Acier." Ann. des Mines, 8th series, July to August, 1885.

‡ "Etude Métallurgique." Ann. des Mines, July, August, 1888.

was determined by passing the gases evolved on dissolving them in hydrochloric acid through an ammoniacal solution of cadmium. It was noted at the time that there was a greater proportion of sulphureted hydrogen (H_2S) evolved at the commencement of the dissolving action than when the last fractions passed into solution. No further notice was taken of this at the time, but more recently, unaware that similar experiments had been described by Osmond, the phenomena was investigated fully in my laboratory. The following is an exact detailed description of the work done:

In each case 10 grams of the steel drillings previously analyzed were placed in a conical flask, and a solution consisting of 10 cc. strong hydrochloric acid and 40 cc. water was poured on the drillings. The liberated sulphur as sulphureted hydrogen was absorbed and oxidized in bromine water and finally weighed as sulphate of baryta ($BaSo_4$).

Between 27 per cent and 30 per cent was dissolved by the 10 cc. acid, leaving 73 per cent to 70 per cent unacted upon. The results given in the following table show the proportion of sulphur in the original metals, that evolved as sulphureted hydrogen from what was dissolved, and the percentage of sulphur in the undissolved metal.

	Sulphur		
	In Original Metal	In 100 parts of Metal Dissolved	In 100 parts of Metal Undissolved
a. Steel	0.041%	0.055%	0.035%
b. ,,	0.055	0.056	0.054
c. ,,	0.090	0.133	0.071
d. ,,	0.180	0.443	0.067
e. ,,	0.066	0.087	0.057
f. ,,	0.044	0.080	0.030
g. ,,	0.096	0.137	0.078
h. ,,	0.055	0.077	0.046
i. ,,	0.076	0.087	0.071
j. ,,	0.068	0.073	0.066
Cleveland Pig	0.104	0.180	0.070
Hematite No. 3	0.040	0.111	0.014
,, Forge	0.110	0.314	0.034
,, White	0.605	1.700	0.162
,, No. 3	0.057	0.077	0.049
,, No. 3	0.068	0.120	0.046
Metallic scum from Basic Pig	5.400	8.440	2.360
Basic Pig	0.107	0.132	0.082

It was found in the cases where the relative proportion of manganese dissolved was compared with the sulphur evolved, that they approximated to MnS, unless the manganese was insufficient to form that compound with the sulphur in the original samples.

The following example may be taken as representing the general rule:

	Original Steel	30% Dissolved Portion	70% Undissolved Portion
Sulphur	0.180%	0.443%	0.067%
Manganese	1.066%	1.483%	0.843%

Sulphur in fraction dissolved	0.443%
Sulphur in undissolved steel	0.067%
Difference	0.376%
Manganese in fraction dissolved	1.483%
Manganese in undissolved steel	0.843%
Difference	0.640%

If the sulphur were originally associated with manganese as MnS, 0.376 per cent would require 0.647 per cent manganese, and as the actual amount found was 0.640 per cent, it may be accepted that this experiment confirms the direct evidence of Osmond & Werth.

With the aid of the microscope, Professor Arnold detected the presence of independent sulphites in steel castings, and later Mr. Thomas Andrew proved their existence as minute isolated specks widely distributed in steel rails. It was the professor who described the optical appearance of sulphide of manganese as dove colored and sulphide of iron as pale brown. Every metallographer is now quite familiar with the dove-colored sulphide, as it is a normal constituent of commercial steels.

In large steel castings the form assumed by the sulphide is that of imperfect globules, plates and irregular particles partially surrounding the primary crystals.*

In the same steel, after annealing, it is mainly by the position of these globules that portions of the borders of the primary

* By "primary crystals" is meant the first crystals which form when the steel passes from the liquid to the solid state.

crystals can be traced, for the original forms of the crystals are effaced by heating in the annealing furnace and are replaced by secondary and much smaller crystals.

When the sulphur is high, the sulphide forms more or less continuous envelopes round the crystals and are sometimes a serious cause of weakness. That they do not generally encircle the primary crystals completely can easily be understood when one considers how the crystals grow in a cooling mass of steel.

Professor Arnold, in his paper on "Steel Castings," described what he tentatively called a sulpho-silicide of iron, which he states is invisible under the microscope before etching and is apparently of a metallic nature. It is described as having segregated in a minutely granular form. Reference is made in that paper to certain experiments conducted in my laboratory, which, it was stated, tended to prove the existence of this silico-sulphide. As the experiments referred to proved the presence of silicates in steel, not silicides, I propose to describe them here together with others made to ascertain the nature of the scoriaceous particles.

Having identified the minute particles, described by me at the time as scoriaceous matter, owing to their slag-like appearance, and not being certain what they really were, an endeavor was made to separate them mechanically, and with this object a steel casting was drilled with a dry drill until about seven pounds of steel in the form of drillings were obtained. These were placed on a fine sieve and the finest powder was removed. It was assumed that the separate but imbedded particles were of a scoriaceous nature, and that as the drill passed over and through them they would be crushed to fine powder, the steel or metallic portion meanwhile taking the form of shavings. The fine powder actually sieved off was freed from metallic particles by a magnet, and the remaining non-magnetic portion was analyzed for sulphur and silica.

The analysis was as follows, viz.:

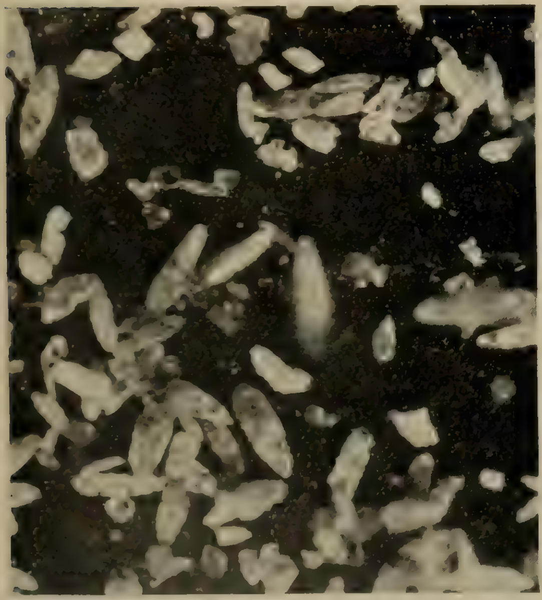
Sulphur	4.30%
Silica	40.80%

The quantity of dust was too small to make a complete analysis. Manganese and iron were both present, but silicide of iron was absent.

Excepting the proof that there were sulphur and silica in the fine dust, the experiment was unsatisfactory.

In many cases it was observed on examination of the scoriaceous specks in forged steel that the ellipsoidal particles were not homogeneous, nor were they all of the same color, and that dilute nitric acid dissolved some of them, whilst others appeared to be inert to the action of acid.

Taking advantage of this apparent difference in solubility, experiments were made upon several samples of steel, but instead of using drillings, bright scaleless pieces of the steel, free from rust, were employed; each of these was immersed in half a liter of 10 per cent (1.40 Sp. Gr.) nitric acid in water and were allowed to remain till nearly all the free acid was saturated. The liquid was carefully decanted off, and each piece of steel was rubbed with the finger to loosen the adherent slime, which was then washed off into the beaker containing



No. 1. Silicate of Manganese. Separated from a Crank Shaft. ×50.
No. 2. Silicate of Manganese Containing Globules of Sulphide of Manganese. ×500.

the heavy, insoluble residue. This was carefully washed by decantation and all the lighter flocculent carbonaceous matter floated off. The residue was finally washed with alcohol and dried. It was of a pale green color. It was placed on a glass

slide, examined under the microscope, illuminated by vertical light and photographed. One of the residues is shown in photograph No. 1. The shape of the particles is ellipsoidal. The steel from which this was taken was a piece of forged crank shaft. The shape of the particles suggest that in the ingot originally they had been globular, but during the forging process they had been drawn out so that their longer axes were in line with the axis of the shaft.

The residues in all cases had the same pale green color. An analysis gave the following result:

Protoxide of manganese (MnO)	42.00%
Protoxide of iron (FeO)	Traces
Silica	56.00%

The approximate chemical formula is: $(MnO)_2(SiO_2)_3$. Under different conditions of composition of the steel and its temperature and the size of the casting, it is possible the analysis of the silicate may vary considerably.

Now as the shape of the ellipsoidal particles of silicate of manganese is identical to those of the sulphide of manganese, it is most probable that they are often mistaken for the other. A careful search was made for means to identify them. It was soon found that frequently in very large masses of forged steel the silicate and sulphide are associated, the latter usually being imbedded in the silicate, and that they could be plainly identified by the difference in color. Photograph No. 2 is an example which shows particles of sulphide of manganese embedded in the silicate.

The best way to proceed when searching for these bodies is to examine the sections after perfectly polishing their surfaces previous to etching, for it is on such surfaces the sulphides and silicates are easily detected. As a general rule if the separate particles are different in color, those of a pale dove color may be tentatively accepted as sulphide. If the two bodies are associated in one of the patches, the difference in optical appearance is at once seen and the independent patches may be compared with it and thus identified as being different.

It is not always easy to tell the difference between the two bodies when the individual particles are very minute, but as the reflected actonic light from sulphide of manganese is greater

than that from the silicate, a sensitive dry plate in the camera will show a great contrast between them.

Without etching, whilst the object is still under the microscope, a drop of sulphuric acid (1 of strong acid to 3 of water), should be placed on the surface.

No. 3. Steel Forging, Showing Large Dark Plate of Manganese Silicate and Lighter Particles of Sulphide. ×500.

No. 4. Brittle Steel Casting. Heat Tinted, Showing Manganese Sulphite Surrounding a Crystal Grain. ×350.

From each sulphide particle a bubble of gas will be evolved, but no gas will form over the pure silicate. That this gas is H_2S can be proved by cementing a minute cell or ring of glass on the polished surface of the specimen before adding the acid, and placing over this a cover-glass moistened with a solution of lead acetate. In a short time a dark stain of lead sulphide will form, easily seen when under the microscope. After the sulphide has been dissolved and the acid contains the manganese as sulphate, the liquid may be removed in a capillary glass tube and blown out on to a glass slip and mixed with a similar volume of nitric acid and a speck of bismuthate of soda. A permanganate reaction will result, easily seen under the microscope.

The areas of sulphide and silicate can best be seen after "heat tinting" the polished specimens to a light brown color,

when the patches appear relatively light on a brown ground. The temper color must not be allowed to pass to blue, otherwise both the silicates and sulphides become brown, due to the formation of films of the higher oxides of manganese.

Photograph No. 4 represents the appearance of a very small, brittle steel casting, high in sulphur, after annealing for twenty-four hours, when polished and heat tinted in the manner described to a brown color. The white parts represent sulphide of manganese only, as silicate was absent. If any silicide of iron or manganese were present, the "heat tinting" would have revealed it, but in no case was it detected; indeed, theoretically free silicide cannot exist in steel castings.

The examination of a large number of laminated, broken tensile test pieces of steel has proved that the lamination is caused frequently by the presence of green silicate of manganese, almost always accompanied with a little sulphide.

The presence of the larger proportion of silicate may, from a mechanical point of view, under certain conditions, be serious, and it is most important that the causes leading to its presence should be carefully studied by metallurgists. It is evident that the prime cause is oxygen.

It is known that open-hearth steel, finished with too much oxide in the slag, is believed to be oxidized, although the correct proportion of manganese and silicon have been added. Such steel is not so good as properly made material, and is often red-short.

When molten steel is being poured, the stream of liquid metal is exposed on all sides to air, which undoubtedly gives oxygen to the metal. This must yield silicate of manganese in the steel, most of which probably floats to the top of the metal after it enters the mold, yet it cannot all escape in that way, for some of it is found in the steel itself. The following problems require solution:

(1) Is the silicate partially soluble in the molten steel and liberated at the point of solidification?

(2) May not red-shortness in steel sometimes be due to this silicate?

In conclusion I would urge metallurgists to study the conditions favorable to the production of silicate of manganese in steel, with the object of avoiding it, and would suggest as

one direction in which trials should be made when the whole contents of a ladle are poured into one large ingot mold, that the steel should be run from the bottom of the mold, and that before the metal is allowed to flow from the ladle the vertical trumpet mouth of the runner should be luted to the bottom of the ladle so as to enclose the nozzle, and thus avoid the possibility of the fluid steel coming into contact with air before it passed into the mold.

METALLOGRAPHY AT THE UNIVERSITY OF MICHIGAN *

By WILLIAM GABB SMEATON

Instructor in Chemical Engineering

Written for The Iron and Steel Magazine

PREVIOUS to the spring semester, 1903, a limited amount of metallographic research was carried on under the direction of Professor Campbell by advanced students in technological chemistry and assistants, but instruction was not regularly given until the above date, when a laboratory course comprising one afternoon's work a week was offered by the author every second semester. Beginning with the present calendar year, one lecture per week on the micro-structure of iron and steel and its relations to the mechanical and thermal treatment, is given each semester, to precede or accompany the laboratory course, which likewise is given each semester. In addition, the research course in chemical technology, involving five laboratory periods per week throughout the semester, has been extended to include metallography.

We are supplied with one Sauveur polishing machine, geared to 1,250 revolutions, and a small dental lathe geared to 1,350 and 1,750, which is provided with brass-faced discs, five inches in diameter, having a clear polishing surface. The latter machine has also a foot-power attachment. Besides emery and carborundum wheels, we use emery, carborundum, rouge, alumina and silica polishing powders, all of which are prepared in the laboratory. The two former are made from commercial

* Contribution from the chemical laboratory, University of Michigan, Ann Arbor, Mich. Received January 16, 1905.

emery and carborundum by grinding for eight hours in a jar mill, until all will pass a two hundred-mesh sieve, and then they are levigated and separated into three grades, the two finer grades alone being used. Rouge we prepare from pure ferrous oxalate by calcination at as low a temperature as possible in a muffle; alumina in a similar way from ammonia alum. We have found the polishing materials supplied by Sauveur satisfactory, but prepare our own for the sake of the practice afforded the students. The finest grade of a levigated pure silica has been found serviceable for bas-relief polishing in place of rouge or calcium sulphate. The coarser powders are used on pocket drilling, while rouge and alumina are spread on unfinished worsted or broadcloth.

Our polishing practice has developed into a routine, and, while the students are recommended to try other procedures, they have without exception adopted the following system: (1) Facing and beveling on the rough emery wheel, making the furrows uniform and shallow towards the last of the operation by decreasing the pressure against the wheel; (2) continuing this operation on carborundum powder * until the furrows are quite shallow and perfectly uniform; (3) the final polish is then quickly obtained with rouge or alumina. I have tested this procedure on specimens of all degrees of hardness, from soft dental alloys to the hardest of tool steels, and find it perfectly satisfactory. With a little experience, eight minutes suffice for the preparation of a fairly good surface, although twenty minutes are needed for first-class results. Possibly this procedure has a greater tendency to form surface films than some other methods, and the tendency is naturally augmented by the high speed of our wheels. This is particularly the case with the Sauveur wheel with a diameter of eight inches, where the center for a space of three inches is not available for polishing.

We have used a specially constructed carborundum wheel in place of the powder. When the difficulties attendant upon the production of a suitable binding material are overcome, it will do away with the necessity for the coarser powders.

Unless otherwise desirable, we prepare small sections of

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* Hard steels polish on carborundum almost without scratches.

0.5 to 1.0 square centimeter area. After etching, they are repeatedly washed in distilled water for half an hour to give the etching agent opportunity to diffuse entirely out, and then they are dried in a desiccator over phosphorus pentoxide under reduced pressure. I have tried in a good many other ways to preserve specimens indefinitely, *e. g.*, by washing with ether, alcohol, benzol, benzine, etc., and by using water saturated with hydrogen and drying in a current of hydrogen. The above method is by far the best. It is essential to remove the etching agent completely in order to preserve the dried specimen unchanged.

We keep a large stock of etched sections for class use and mount them with sealing wax on small slides, made by cutting ordinary slides in two, to avoid misplacement. With the following simple device (Fig. 1), it is possible to mount a section of any shape whatever very quickly and with the minimum of trouble.

It consists of a heavy steel block. To its upper surface is cemented a glass plate, on which the specimen is placed face down. From the block rises a heavy turned steel rod, up and down which slides a broad, accurately adjusted collar carrying the slide holder. The manipulation is obvious.

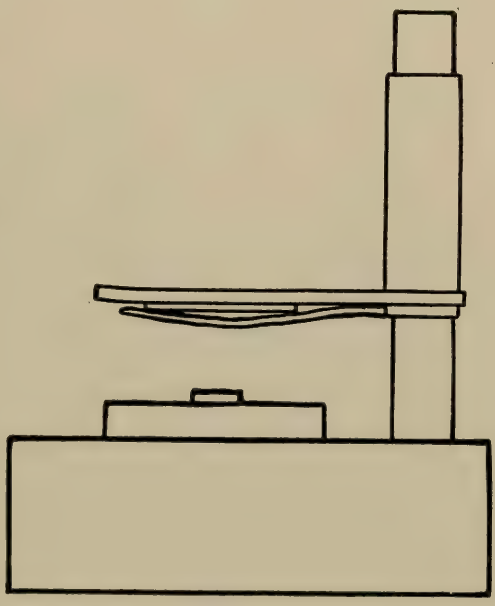


Fig. 1

The present stock of microscopes comprises four with stationary tables, one Sauveur microscope with revolving table, and a petrographic microscope. A full complement of accessories is included. For illuminating we use a Welsbach, and in place of the ordinary sheet-iron chimneys with iris shutters, substitute tin chimneys with perforated asbestos discs. As an exercise, the students determine the magnifying power of the microscopes with different eyepieces and objectives. We have observed quite different mag-

nifications on interchanging oculars and objectives of the same magnifying power. All our calibrations are given in microns.

The eyepiece grating has been found serviceable for micro-analysis, particularly a specially constructed grating with forty-nine squares. With this grating the carbon-content of annealed low and medium carbon-steels is easily and accurately determined, our measurements having always checked those made by the customary methods. The grating is furthermore serviceable in studying the effect of quenching temperature upon the micro-structure of low carbon-steels.

The photographic equipment comprises a Thompson hand-feed arc illuminator, a Queen camera with extension bellows of five feet draw, and a full line of supplies. An overhead water bottle is connected with the water cooler and gives it automatic circulation.

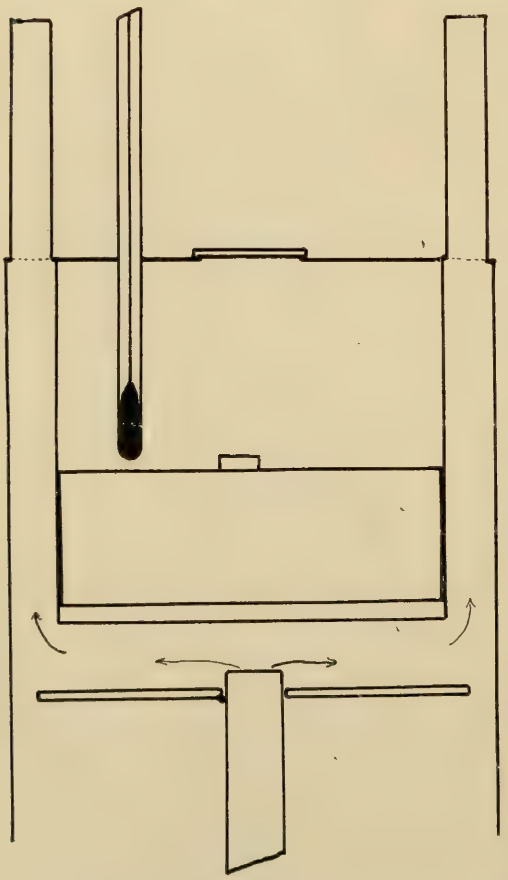


Fig. 2

Hitherto our researches have dealt largely with the etching of polished steel surfaces, and some of these results will constitute the subject-matter of succeeding communications. For heat-tinting the following air-bath (Fig. 2) has proven invaluable.

The bottom is an iron plate $\frac{1}{4}$ inch thick, 4 inches in diameter, to which is riveted a copper cylinder 4 inches high. Outside is an asbestos cylinder 6 inches in diameter, 7 inches high. Its upper surface is flush with the top of the copper cylinder, and the two are joined with asbestos. Three chimneys provide satisfactory draught, and an asbestos shield prevents loss of heat by downward radiation. One Detroit burner heats this bath to above

500° C. in fifteen minutes. The top is covered air tight with mica, having an opening two inches in diameter for inserting the sections. This is covered by a glass plate. The temperature is easily regulated by means of a nitrogen-filled thermometer and any desirable atmosphere may be introduced.

Unusually good facilities are afforded for heat treatment work. Our pyrometer room is centrally located and has leads to all the muffles and electric furnaces. The galvanometer was designed by Professor Campbell and has 6,780 ohms internal resistance and a low temperature coefficient (0.00006), thus avoiding the necessity of considering variations in external resistance and room temperature. Although the internal resistance is so high, the instrument deflects 27 mm. per millivolt, or about an average of 1 mm. for 2.8° C. The telescope reads to 0.1 mm. In subjecting steel to desired heat treatment our experience has shown that the temperature can be controlled with certainty to within less than 2° C., and usually to within 1° C. Researches correlating heat treatment with micro-structure constitute a large part of our program of work.

Ann Arbor, January 12, 1905.

NOTES ON THE BLAST FURNACE *

By JOHN M. HARTMAN

THE bosh of a blast-furnace is filled with glowing fuel when working properly. On top of this bed of fuel is the short zone of fusion in which all the ore and limestone disappear, leaving the fused material, iron and cinder, to run down through the bed of fuel in the form of shot. The bosh must be low enough to permit the zone of fusion reaching above it. Above the zone of fusion is the zone of carbonization where the ore receives its final reduction and carbonization before fusion. This zone is filled with finely disintegrated fuel, ore and lumps of lime. When the furnace is not scaffolded this zone determines the pressure of blast by its depth. In the charging of fine ore in the furnace it rattles down through the fuel and limestone to the top of the zone of carbonization, making the zone

* "The Iron Trade Review," November 10, 1904.

deeper and necessitating higher pressure of blast. Old furnacemen with light blowing engines blew the furnace down until the zone of carbonization becoming less deep eased up the pressure, when the work of filling commenced again. Sparks in the gas show the zone of carbonization is disturbed.

No new ore arriving on the zone of carbonization, the fusion below melts away this zone, making it thinner. If the plant is well equipped with reserve power in the engines, boilers and stoves and the furnace is driven more rapidly, the accumulation in this zone can be prevented. Furnacemen fear to do it lest the ore coming down unreduced give poor iron. This will soon show by the color of the cinder if the ore is unreduced.

This brings up the question of fast driving. In the Mt. Hope charcoal furnace the ores were exposed three hours in making foundry iron, disintegrated magnetic ore being used. In the Catalan forges concentrates are reduced to wrought iron in two hours. In the Alice furnace of 6,500 cubic feet capacity, No. 3 iron was made with six hours' exposure and 59 feet of working height, using Mesabi ore and a blast temperature of 900° with cast-iron stoves. The burden carried at the Alice furnace was equal to the burden carried by furnaces having firebrick stoves. This, by the way, is due to firebrick stoves not having the proper amount of heating surface to carry 1300° through the blow, as the heat varies and runs down to 1100° with 450° temperature of escaping gas at chimney. Maintaining 1300° uniformly is only possible where the firebrick stoves have 5 square feet of surface to each cubic foot of air, and use equalizers to maintain a constant temperature.

When firebrick stoves become glazed they require far more gas to heat them up, and the blast is more irregular in temperature from the beginning to the end of the blow. The glazing of the brick work can only be prevented by large heating surface and burning the gas in a separate combustion chamber. When furnacemen say they only need 500 to 1000° of hot blast it will be found the stoves are too small or they are afraid to run the risk of a heavy burden.

With firebrick stoves there will be no trouble passing the stock through in six hours, as the Alice, with pipe stoves and 900°, did it with as good fuel economy as furnaces with brick stoves. What is the use of high furnaces so far as hearth is con-

cerned? The 17-foot hearths are too large, and to get penetration small tuyères and high pressures to force the air through the hearth are required, causing a great expense in blowing.

One ton of coke having 85 per cent of carbon requires 145,000 feet of air to burn it, or say one ton of coke used every four minutes. This with a burden of 2.16 to 1 would give a daily output of 60 per cent ore or 450 tons per day if ores are broken small. Thirteen feet of the largest hearth that has been found practicable and 35,000 cubic feet of air actual delivery will be the proper volume to blow it. The limit of the furnace is the hearth, and with a 60-foot stock column there will be ample time for reduction providing the ores are broken small.

Irregularities in the quality of the iron are largely due to unreduced ores and limestone in the form of large lumps which the furnace has not had the proper time to reduce. All ore should be crushed to three-quarter-inch cubes before being placed in the furnace.

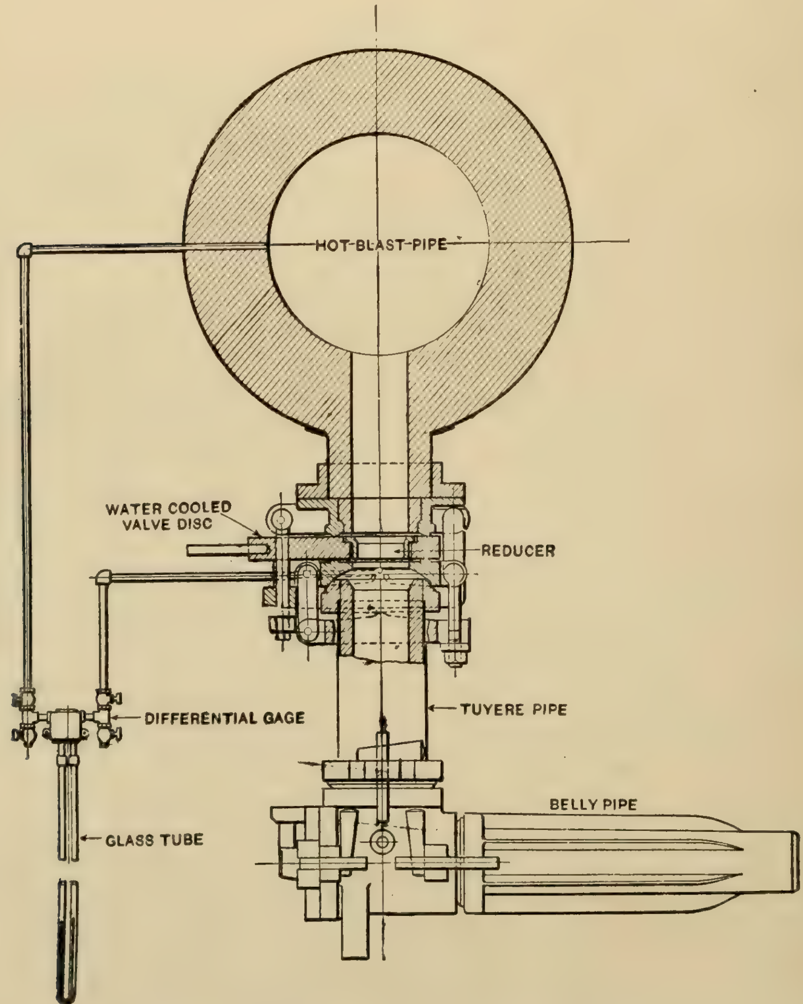
The first and easy part of the reduction of ores takes place before reaching the zone of carbonization. In this zone the exterior of the ore parts with the balance of its oxygen. As the exterior ore parts with the oxygen it absorbs carbon, causing it to swell and peel off. As it disintegrates the lump becomes smaller, allowing the carbon finally to get into the center, by which time the ore is thoroughly reduced and carbonized, if the furnace settles regularly.

It is cheaper to crush the ores and limestone at a small expense and thereby get better fuel consumption with more regular iron. What can be done mechanically at low cost should be done to avoid doing it chemically at a great expense.

When unreduced limestone gets into the zone of fusion the iron sponge, owing to its high heat, will seize on the carbonic acid, split it up and the sponge be oxidized, giving a scouring slag. When too much stone is used it gets to the tuyères and prevents the air reaching the fuel at once. Instantaneous combustion at the tuyères is required for good work.

The low furnace will work with much less blast pressure, requiring less powerful blowing engines, less boiler capacity and the use of less gas to give the blowing power. The loss with high pressures is enormous. Extra firing, with its cost to keep up steam, often has to be resorted to.

With these high pressures wasting the power there comes another loss. A new plant fitted up and tested, it will be found that at 2-pound pressure the loss in leakage will be about 2 per cent. Ten-pound pressure increases it to about 25 per cent. From this it can be judged what the leakage is at 25-pound pressure. The power here wasted is larger than is generally known. The pressure has increased with the high furnaces.



Method of Attaching Differential Gauge

Taking the average of charges on a coke furnace 80 feet high it will be found there is exerted on the zone of fusion a pressure of 3,270 pounds per square foot, or, say, 23 pounds per square inch. If the furnace is increased to 100 feet high this pressure will be 32 pounds per square inch. The side thrust of

the stock in the bosh packs it so tight together that it forms a constant bridge and we have to rely on the burning away of the coke below this jam to keep the furnace moving. The taper of the bosh acts as a wedge to jam the fuel closer together. At times this jam becomes so great that the stock is held up, the pressure increased and a large volume of coke burned from underneath the jam, making a great cavity before the jam lets loose and the stock comes down. When it does come we have a mass of gas, coke and ore dust that completely covers the plant so that it cannot be distinguished until the dust blows away. The high pressure finding a sudden relief makes the blast rush through the tuyères, which fires the gas in the interior of the furnace, causing an explosion that lifts the bell and hopper.

When this slip occurs the zones of fusion and carbonization are destroyed. The furnace then has to form new zones of fusion and carbonization. The result is irregular iron. The jam on the bosh can be prevented by letting the blast work harder on the walls, taking care at the same time that sufficient blast penetrates through to the center. Working hard on the walls soon destroys them unless water cooling of the brick work is provided. The use of bosh plates in rows about 30 inches apart will prevent this to a certain extent, but it makes a rough irregular bosh wall, causing the furnace to make numerous short slips.

These bosh plates only cool the bosh where they are put in. The cooling power extends but a short distance from them. The use of bosh jacket covering and cooling the entire bosh surface completely preserves these walls and gives a smooth bosh where there is less liability for small scaffolds. The water in this case has no chance of getting in the furnace, as the pockets of the bosh jackets are not over 24 inches deep. The pressure of blast inside the furnace is so much greater that even if a leak started the blast would blow back the water and prevent any water entering the furnace. The leak in this case is immediately located by the water turning white, while with the bosh plates the water pressure forces the water into the furnace and it is exceedingly difficult to tell what plate is leaking and much time is lost in locating it. In tests, each extending over one year, at the same furnace and under same conditions it was found that one hundred weight less of fuel was used with the

bosh jacket than with the bosh plates. It has been found that the brick work between the bosh plates has melted out until the contact of the cold air from the outside stopped the melting of the brick work. The bands placed around the furnace to support the walls between the bosh plates covering the brick work prevented the abstraction of heat and the walls melted back to the band. This space was found filled with cinder and coke which had replaced the brick walls. The number of water connections on the furnace should be kept down as far as possible. Less water is required with bosh jackets, and loss of heat is no greater. Fewer tuyères of the larger size can be used if care is taken to get a good dispersion of the blast sideways. The use of hotter blast will give more penetration to the blast, as the hotter the blast the quicker will be the burning of the fuel and the higher the heat at the tuyères where the heat wants to be concentrated. This prevents the formation of tubes of cinder.

Take the old furnace practice with its colder blast. There was always formed at the nose of the tuyère a tube of chilled shots of slag which carried the blast into the furnace until these tubes became chilled and caused high pressure, compelling the keeper to break them away with a pricker rod. A pipe with an eighth-inch opening and 500-pound pressure to the square inch can be stopped and held tight with the thumb alone. How can we expect the blowing engine giving 12-pound pressure to blow through a dark tuyère with the cinder chilled around it?

It will be borne in mind, in making No. 1 iron with a basic cinder, that the cinder melts at about 3500°. At 1300° this cinder is stiff and hard, and unless there is good live fuel at the tuyères to produce then and there a heat of 3500° there will be more or less chilling influence by the blast entering at 1300°. The hotter the blast the quicker the fuel is burned and the heat concentrated at the tuyères. When a tuyère gets dark or shows signs of not working, the pricker rod should be used immediately, and if that does not clear the nose of the tuyère then a small cartridge, costing but a few cents, can be exploded and break through the obstruction, letting the blast enter and get at the nearest fuel, which will soon melt away the obstruction. On this point furnacemen are slack and afraid to use a cartridge costing a few cents, when by its use they can save many dollars. If the blast does not get into the furnace, iron will not come out.

A bright tuyère, as known to the furnacemen, must be distinguished from a glowing tuyère. A glowing tuyère shows but little blast is entering, and furnacemen will use their pricker rod on the bright tuyère because it is not so glowing as the other, while the bright tuyère is doing the most work and the glowing tuyère the least. The same volume of blast should enter each tuyère and work uniformly through the hearth to keep the zone of fusion level. Especially is this required with the large hearths now used.

Use of the Differential Gauge

The differential gauge is provided as follows: Place at the top of the tuyère pipe a valve to be used for cutting off the tuyère when so desired and arrange the valve so that it can be enlarged or decreased by a bushing as required. Then tap a small pipe into the hot blast pipe above the valve and another pipe below the valve and attach to them a bent U of glass. Charge the U-tube half full of water and leave the blast pressure on both sides of the tube. There will be found a difference in the height of the water of the two legs of tube. This is due to the friction of the blast passing through the reducer in the valve. If the tuyère works open and free there will be a difference of, say, one inch of water pressure between the two sides of the tube. If the tuyère has become closed and is not taking blast, there will be no difference in the height of the level of the water in the two tubes. This tuyère then must be opened at once, whether bright or dark. The ratio of difference of the height of water in these two tubes will show the ratio of blast passing through the tuyère. These gauges are small and simple and placed in a case on the side of the casting house. Proper tubes are led to each gauge from the furnace. A simple inspection along the row of gauges, which we call a differential gauge, will show at once what tuyères are taking blast and what are not.

The tuyères that are not taking blast have become clogged from some cause and an opening must be made in the material at the front of the tuyère at once to prevent lopsided working of the furnace, and disturbance of the zone of fusion. The first thing to be done is a vigorous application of the pricker rod, and if this does not give an opening then the cartridge

must be used. Many furnacemen have feared the use of the cartridge. It should be placed in careful hands, but there is no way so cheap and quick as the use of these small cartridges to open up the tuyère.

Blast entering the tuyères does not always take a straight course but wanders around through the hearth, where it meets the least resistance. Instances have been found where the blast from one tuyère was passing across the nose of another tuyère to reach the cinder notch. These little gauges, small and cheap, are invaluable to a keeper who will pay strict attention to them. If he does not he had better throw them away and go on with his old rule of thumb way of working the furnace. The gauges have been used for twenty years, but they will not prick a tuyère nor explode a cartridge.

Seventy years ago the cane juice was boiled to sugar in an open pan with a fire beneath. It was difficult, almost impossible, to produce exactly the grain and quality of sugar. If it would crystallize too much it would solidify in the pan and have to be chopped out. This was partly overcome by boiling with steam through a coil, but even here it required the greatest care and skill. Even with that the sugar would solidify at times and have to be chopped out of the pan. This was followed by closing the pan, forming a vacuum in it and boiling the cane juice in vacuum. Here the trouble of solidifying also followed them and increased as the vacuum pans were made larger. Finally they resorted to the use of gauges placed in different parts of the pan to tell them just what was going on in the pan. At the present time a sugar boiler will boil sugar exactly to the grain wanted and to the quality, but he stands over that pan watching every gauge and all the indications that he has to show him the progress of the boiling.

Why should a furnaceman not resort to gauges and all other means that will show him just what the furnace is doing and thereby produce steady, uniform results?

DRY AIR IN THE BLAST FURNACE *

WE commend to those of our readers who are interested in the manufacture of pig iron the paper read by Mr. James Gayley at the New York meeting of the Iron and Steel Institute. Mr. Gayley deserves credit for an original research carried out at considerable expense, and with eminently satisfactory results. He has arrived at certain conclusions which we hold to be wrong. About the facts we have no doubt. We take exception to the hypothesis which he has framed to account for the facts. The questions raised are extremely attractive, both from a chemical and a thermal point of view, and we trust that they will be discussed by chemists and metallurgists very fully and very fairly.

We can narrow the issues by confining our attention to a few facts taken at haphazard from many. Mr. Gayley has arrived at the conclusion, for reasons set forth in his paper, that a considerable advantage would be gained if blast-furnaces were supplied with dry air instead of with air containing moisture. It is a familiar truth that cold air will carry less moisture than hot air. Availing himself of the fact, Mr. Gayley constructed a large cooling chamber, fitted with multitudinous pipes, through which brine far below the freezing point flowed. The air on the suction side of the blowing cylinders passed through this chamber, was cooled down, deposited its suspended moisture, and entered the blast engines well desiccated. The result, as set forth, was that while with normal blast the output of the experimental furnace was 358 American tons per day, and a coke consumption of 2,147 pounds per ton, with dry blast the output became 447 tons, and the coke 1,726 pounds per ton. Thus we have a saving of 421 pounds of coke per ton of pig. The precise figures given by Mr. Gayley show that during a period of 13 days the average moisture in the atmosphere was 5.66 grains per cubic foot, and in the dried air 1.75 grains. Sixty-nine pounds of water were removed from the blast per ton of iron produced, which represents an average of 23,192 pounds, equivalent to 2,784 gallons, for the 24 hours. This weight was calculated from the volume of air blown into the furnace, as

* "The Engineer," November 18, 1904.

shown by piston displacement. For four days during the above-named period the water caught in the tank underneath the refrigerating chamber amounted to an average of 21,561 pounds, equivalent to 2,588 gallons, for the 24 hours, which is in very close agreement with the other figures.

With these data before us we are in a position to consider what actually took place. The first fact is that under no circumstances can water enter a blast furnace unless a tuyère is leaking. All the 69 pounds of water per ton of iron made was converted into superheated steam in the heating stove. It is a weak point in Mr. Gayley's paper that he only incidentally mentions the temperature of the blast, which, he says, was not much more than 800° F., and could not be more because of the defective construction of the stoves. The temperatures of the blast with dry air and moist air are important factors. We are left to believe that the drying of the air made no difference. So far, then, we have injected into the furnace 69 pounds of superheated steam with a temperature of at least 800° F. per ton of iron. At the blast pressure each pound of saturated steam would have a volume of about 20 cubic feet. We do not pretend to know what the volume would become when superheated, because there is very little settled by direct experiment; but if we assume that the volume was trebled, we have $60 \times 69 = 4,140$ cubic feet of steam per ton, a volume quite insignificant as compared with the 40,000 cubic feet of air per minute sent through the tuyères. Taking the figures in another way, about 21,000 pounds of steam went into the furnace, while 1,001,280 pounds of iron were made. To convert 21,000 pounds of water into steam would require about 2,100 pounds of coke per 24 hours. The actual saving effected was, however, 188,189 pounds of coke per 24 hours, which is quite out of all proportion to the saving effected by removing water; and, furthermore, it must be remembered that the coke in the blast-furnace did not evaporate the water; that was done in the stove by waste gas. Again, the quantity of water going in in the air is as nothing to that contained in the ore. We may therefore reject, once and for all, the theory that the saving effected was secured by avoiding the loss of heat expended in converting suspended moisture in the air into steam. To the chemist we must leave the consideration of the effect on the working of a blast-furnace of the injection

of a comparatively small volume of superheated steam. Possibly dissociation would take place not far from the tuyères; but this would not represent loss, for further up in the furnace the hydrogen liberated would, no doubt, combine again with the oxygen, and give back all the heat energy expended in bringing about dissociation.

It is not necessary, however, to cast about for recondite chemical or thermodynamical explanations of how or why economy was secured. The saving was, we hold, the result not of using dry air, but of using cold air. The chilling of the air augmented its density, and virtually increased the delivery of the blast engines, while the pressure, and, consequently, the work done, remained unaltered.

Mr. Gayley gives a table of temperatures but not volumes. We may supply the deficiency for a few taken at hazard. The inlet or suction temperature being 70° F., the volume per pound is 13.342 cubic feet, the chilled temperature from the cooling chamber to the blowing tubs was 20° F., and the volume 12.08 cubic feet; on another occasion the atmospheric temperature was 80°, the volume of one pound was 13.59 cubic feet. This was reduced in the refrigerating chamber to 22° F. and 12.13 cubic feet. We have here a very ample augmentation in the weight of the air blown in, the blast pressure remaining unaltered, and we find accordingly that while "before applying the dry blast the engines were running at 114 revolutions and supplying 40,000 cubic feet per minute, the revolutions were gradually reduced to 96, thereby reducing the volume of blast over 6,000 cubic feet per minute, and increasing the efficiency of the engines by 14 per cent. With dried blast 96 revolutions per minute of the blowing engines burned nearly 1 per cent more coke and produced 89 tons more pig iron in 24 hours than 114 revolutions on natural air. The reduction in the revolutions resulted in a gain of 150° in temperature of the blast, which even with this increase, through lack of area in the waste gas ports of the stove, did not average above 870°." As we have just seen, the reduction in volume reached as much as 12 per cent, which fairly enough approximates to the 14 per cent given by Mr. Gayley.

The blast-furnace is a remarkably delicate chemical apparatus, and the facts before us open up a field for inquiry that has

scarcely yet been touched. It is well known to most iron makers that the weather has a very considerable effect in modifying the output and quality of the iron. We can call to mind a furnace in Staffordshire which obstinately refused to make anything but white iron when the wind blew from a certain quarter. We venture to think that we have shown that no reason whatever can be assigned for the improved working of Mr. Gayley's furnace on the ground that the air was dried. On the other hand, things become pretty clear as soon as we remember that the density of the air was augmented some 10 or 12 per cent by the cooling. Even then, however, something remains to be explained. We gather that the experimental furnace had not been working with sufficient blast; consequently it could not carry an adequate burden even by driving the engines hard. Cooling the air had the same effect as augmenting the output of the blast engines. Whether, however, the increased density of the blast and the absence of a small quantity of superheated steam played any special part in the internal economy of the furnace is a matter which deserves careful inquiry. We trust that Mr. Gayley will be able to put iron makers under more obligations when he has pushed his researches somewhat further.

A SIMPLIFICATION IN CARBON COMBUSTION APPARATUS *

By PORTER W. SHIMER

IN the writer's paper on "Carbon Combustion in a Platinum Crucible" (J. A. C. S., Vol. XXI, p. 557) is a paragraph recording the results of two experiments on carbon determination in steel, with the copper oxide tube left out of the train. In combustion in the crucible, using no copper oxide, only about 90 per cent of the carbon was oxidized to CO_2. When asbestos coated with copper oxide was placed on top of the carbon in the crucible, the results were very much better, but still slightly below the correct figures.

Auchy (Vol. XXIV, p. 1206) gets quick and useful results, though still a few thousandths per cent low, by placing the filter, carbon side up, on the bottom of the crucible and filling

* "The Chemical Engineer," November, 1904.

to near the oxygen inlet tube with finely ground, thoroughly ignited copper oxide. The copper oxide tube is omitted, and the blast lamp is used for ignition. Purified oxygen is used at a rate of 4 to 5 bubbles per second, and 10 minutes is allowed for combustion. The cause of all these low results is that the carbon begins to be oxidized before the copper oxide gets to a red heat. By filling the crucible in the manner to be described, this difficulty is overcome. (See Fig. 1.) The results are fully up to the standard and the copper oxide tube may be safely omitted. First pour finely granular, well-ignited copper oxide to the depth of one-eighth inch upon the platinum disc at the bottom of the 60 cc. crucible. (Vol. XXIII, p. 227.) On this place the disc of dry asbestos and carbon, with the carbon side down. On top of this place a No. 1 porcelain crucible, cylindrical form, and press it down firmly. Put the lid on the crucible and pour finely granular copper oxide over it until the annular space between the two crucibles is filled. The copper oxide must be well ignited and freed from the finest powder by passing it over a 200-mesh sieve. The porcelain lid is now removed and a disc of ignited asbestos paper, having the diameter of the crucible at that point, and provided with a hole in the center three-eighths inch in diameter, is placed on top. The rubber band is wetted and the stopper is put in place and tested for tightness. Let air sweep rapidly through the apparatus for a minute or two, then attach the absorbent and make the combustion, using a blast lamp surrounded by a sheet-iron cylinder open in front. For ordinary steels 20 minutes combustion in air is sufficient. By use of oxygen this time may be reduced where highest speed is necessary.

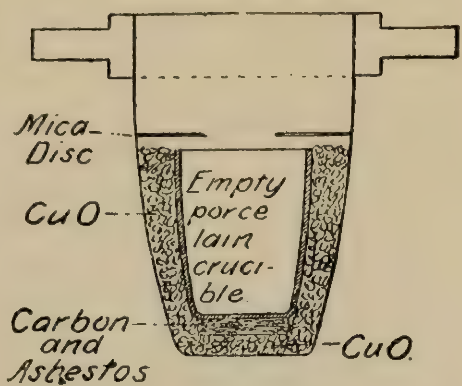


Fig. 1

In this arrangement the copper oxide at the bottom and sides of the crucible becomes red hot at about the time the carbon begins to burn. If the porcelain crucible is left out and the platinum crucible is simply filled with copper oxide

the result is that, when the carbon begins to burn, the mass of copper oxide in the middle of the crucible is still far below a red heat, and any carbon monoxide formed will pass through it unoxidized. Using the porcelain crucible, however, this dead space is cut out and the copper oxide between the two crucibles is brought to a red heat in time to do its work. On a steel standard containing 1.055 carbon the results obtained were 1.057, 1.053, 1.056, 1.058, 1.069; average, 1.056.

For organic combustions the crucible has, heretofore, not been used because of incomplete combustion and condensation of volatile decomposition products in the upper part of the crucible and on the stopper where, of course, it is impossible to burn them. By a proper arrangement I have, however, succeeded in getting good results in the combustion of sugar in the crucible, and without use of copper oxide tube. The train consists of, (1) Bottles for air pressure. (2) KOH bulbs. (3) $CaCl_2$ tube. (4) Crucible. (5) Weight $CaCl_2$ tube. (6) Weighed soda-lime tube. (7) Guard tube of $CaCl_2$. Constant weights are first secured on calcium chloride and soda-lime tubes. It is, of course, inadmissible to use water for wetting the rubber band when water or hydrogen is to be determined. A very little finely ground soapstone rubbed on the band will lessen friction and make it easy to get a tight joint. The details are as follows (see Fig. 2): Place ignited asbestos, coated with copper oxide, to the depth of about one-fourth inch on the bottom of a small platinum ignition crucible. On this place a layer of copper oxide which has passed through a sieve of 200 meshes to the linear inch. Ignite well, cool and weigh. Place about 2,000 grains of pulverized and dried sugar on top of the copper oxide and weigh again. Then fill the ignition crucible with the coarser, well-ignited copper oxide (through 20 mesh and over 200 mesh). Now invert the large crucible and bring the filled, coverless ignition crucible, resting in the mouth of a small bottle or test-tube, against the bottom of the large crucible. Turn the large crucible right side up, leaving the ignition crucible inverted upon its bottom. Pour enough copper oxide into it to bring it up to near the bottom of the ignition crucible. Place the stopper on the crucible and sweep out the apparatus with air for a few minutes. It is necessary to have *hot water* circulating through the stopper to prevent condensation upon the bottom of the

cool stopper of the water formed during the combustion. Put on at once the full heat of the blast lamp and heat until combustion is complete. It was desired to make this combustion under the severest conditions, so air was used. Oxygen for organic combustions would no doubt be better.

Combustion took one hour and the results were:

	Theoretical	Found
C	42.10	42.07
H	6.43	6.50
O	51.47	51.43

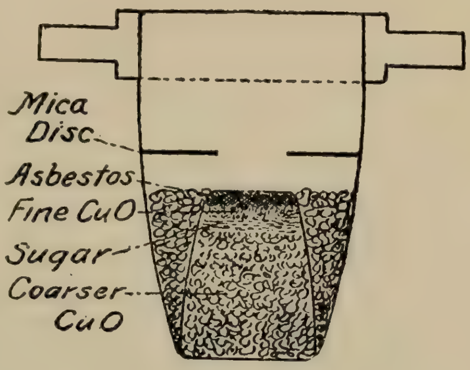


FIG. 2

In this arrangement the copper oxide becomes red hot in time to oxidize the first decomposition products, which must pass down through the copper oxide in the inverted ignition crucible and up through the copper oxide surrounding it, both of which are heated before the sugar. While these results are encouraging it is realized that much remains to be done, and it is hoped that the simplicity and compactness of the method and apparatus will tempt others to try organic combustions in this way.

MODERN METHODS OF TESTING MATERIALS *

Determinations of Hardness, Brittleness and Elastic Limit by Practical and Useful Methods

AN appendix to the valuable Bulletin of the French society for the encouragement of national industry is entitled the "Revue de Métallurgie," and this often contains most valuable papers relating to this department of the work of the engineer. Among these we note in a recent issue an article by M. Guillery, discussing some of the modern methods of determining the resistance of materials of construction, and of their applications to practical work.

Formerly the tension test was considered of the first importance, and its great value is undoubted, although the usefulness of the information to be obtained directly from a mere statement of the ultimate resistance of a material in tension is a matter which is open to question. At the present time it is realized that the practical information desired is that of the behavior of the material under conditions more nearly approaching those under which it is actually employed, and that its elastic limit, its resistance to pressure and to shock are the things which the constructor really desires to know.

At the new workshops at Denain, operated by the company which has succeeded to the business of the old and well-known firm of Cail et Cie., the installation of practical shop methods of testing has been intrusted to M. H. Le Chatelier, and it is an account of these methods which is contained in the paper of M. Guillery.

Leaving aside for the moment the methods admittedly suitable for the research laboratory, M. Guillery discusses the conditions and requirements for satisfactory methods of shop testing. Broadly, the methods used should give precise indications of the quality of the metal, without leaving anything to the judgment of the operator, and these indications should be obtainable at low cost, in little time.

M. Guillery believes that the most important tests for the shops are those of hardness, or resistance, and brittleness, or resistance to impact or blows. Taking the Brinell system of

* "The Engineering Magazine."

determining hardness by the impression made by a steel ball he has employed simple devices for enabling this test to be made in a manner which shall enable strictly comparable results to be obtained by comparatively unskilled persons. Two forms of apparatus are described, one portable and capable of being applied to any portion of a machine or structure, the other fixed for general shop use. In both the pressure upon the ball is determined by a number of disc springs, of the Belleville type, these being inclosed in a cylindrical case with a socket for the steel ball at one end. In the fixed apparatus the pressure is exerted by an arrangement of lever and cams, and when the movement is limited by a stop the springs have been compressed a determinate amount so that the pressure exerted upon the ball is always the same. It is only necessary to polish a small area of surface of the material to be tested, and press the ball upon it in the apparatus, and the diameter of the indentation gives a measure of the hardness and resistance. The tensile resistance is also determined by this test, since it has been shown by experiment that a direct relation exists between the impression made by the ball and the tensile strength of the material. Such an instrument is best calibrated by experiment, and it has been found that an excellent material for calibration tests is the standard bronze used for subsidiary coinage, this being readily obtained and of very uniform composition and strength.

M. Le Chatelier has devised a simple form of diagonal scale engraved on glass, which enables the diameter of the impression of the steel ball to be measured to the tenth of a millimeter by the unaided vision.

The portable apparatus is identical in construction and operation with the stationary machine with the exception that the pressure is exerted by a blow, this being taken up by the springs and converted into a determinate pressure upon the steel ball.

The great advantage of this device lies in the fact that reliable tests may be made upon the actual materials and parts composing the machine or structure under consideration, and that it does not require a separate test piece to be used. In this way all uncertainty as to the manner in which the test piece represents the material in the completed article is removed, and a far greater degree of satisfaction secured. It is possible to test portions of a structure already completed and enable com-

parative results to be obtained from the different parts of the same piece of work.

The impact tests made by M. Guillery are based upon the principle of breaking a nicked bar, following the practice of Barba, Fremont, Charpy and other authorities. For making these tests, however, he employs a very simple and convenient machine, employing rotary motion, instead of the falling ram used by Fremont and others.

The apparatus consists of a sort of small fly wheel, with heavy rim, and crank and gearing device by means of which it may be rotated at a speed of about 300 revolutions per minute. A projection on the face of the wheel is arranged so that it will strike the test bar at the proper place when the latter is pushed towards it; this being done when the wheel has attained the proper speed. A speed indicator shows the velocity of the wheel at any moment, and the loss of speed following the breaking of the bar is an accurate measure of the work absorbed in overcoming the resistance offered. The machine is arranged so that the frictional losses are reduced to a minimum, and since it has been found that correct results are obtained by the use of small bars, or *barrettes*, as they have been termed, the whole apparatus is of moderate dimensions.

By the use of such devices as are described in the paper of M. Guillery it has been found possible to maintain a close control over the quality of the materials used in the large works at Denain, and there appears to be no good reason why such simple appliances should not find useful application in many places. There is no doubt that testing would be much more frequently performed if it could be more readily done; and if the general character of a material could be ascertained within reasonable limits of error directly in the course of its passage through the shop the reliability of the products should be vastly increased.

It is not to be assumed that the use of such methods as are described in the paper of M. Guillery are intended to supersede the employment of accurate and precise testing machines in the mechanical laboratory. The fact that the work has been under the supervision of such a high scientific authority as M. Le Chatelier is sufficient indication that the limitations of the methods have been fully understood and appreciated.

IMPACT TESTS ON THE WROUGHT STEELS OF COMMERCE *

By A. E. SEATON and A. JUDE

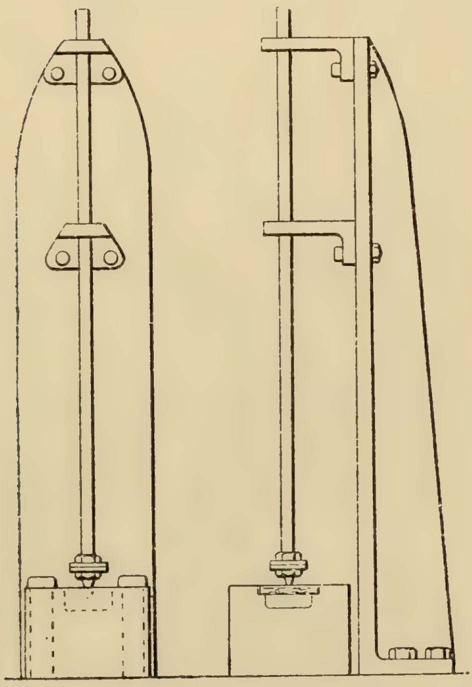
THE objects of this paper are to show some of the characteristics and peculiarities of the wrought steel as supplied by steel manufacturers for commercial purposes, to assist in the development of a more rational method of testing the suitability of such steels for each particular purpose of the engineer, and to point out a few of the peculiarities that are observed in the fracture of test specimens and actual pieces of machinery. It is, in fact, the outcome of the constant endeavor of engineers to avoid the use of material which might be dangerous in the construction of machinery liable to severe alternating stresses, and more especially to attempt to find the very best steel for those parts liable to shock, owing to the inability to make those parts larger in the very fast moving engines so much in demand to-day.

Considerable movement has been made of late towards the establishment of a shock test for steel, conducted on a smaller scale than is the custom with axles, for instance, where the full-sized article is tested. The authors are strongly of opinion that progress in this direction is taking place still too slowly, and it is therefore the aggregate object of this paper to help towards a further appreciation of this valuable test. All the experiments have been made on the ordinary steel, as supplied by various manufacturers as suitable for such parts. Some of the test pieces are from forgings, such as crank shafts, connecting-rods, etc., and others from the bar steel supplied for stud and bolt making. In no case have they dealt with what may be called a "fancy" material, the product of laboratory melting-pots. The tensile tests have been made in a Buckton testing machine, while the shock tests have been carried out in an apparatus designed by the authors to require, as a rule, more than one blow to produce fracture. Such apparatus as shown in Fig. 1 consists essentially of a weight of 6 pounds, arranged to drop freely through 24 inches on to the test bar, Figs. 2 and 3, which rests on fixed supports 3 inches apart. The test bar is

* The Institution of Mechanical Engineers. Abstracted in "The Engineer," November 25, 1904.

4 inches long, so that there is one-half inch overlap at each end. After each blow the test piece is reversed. In the authors' opinion, the apparatus to test the endurance of a material under shock should not be one in which the sample is fractured at the first blow, especially for steels that are soft and are really

FIG. 1.
"Impact" Testing Machine.



"Impact" Test Bars.

FIG. 2.

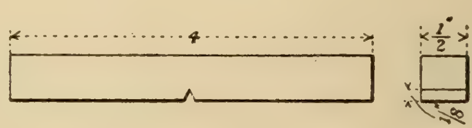
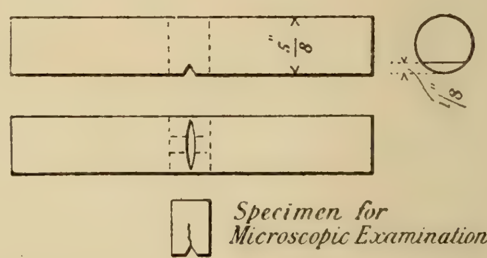


FIG. 3.



very tough, although they admit that for some purposes such a test may be instructive and actually necessary for very high carbon steels. For constructional purposes the engineer is not greatly concerned with steels with more than about 0.4 per cent carbon. Although a large number of experiments have proved to them that in every case, and with every description of structural steel, the power to resist shock has been materially enhanced by oil tempering, they have confined themselves mainly to the examination of the material as applied by the makers rather than after any heat treatment of their own.

At present everybody makes tension tests, and trusts more or less to them alone. One takes up an advertising or scientific article on, say, "Special Nickel Alloys of Steel," suitable for doing all sorts of wonderful things, and the first and main thing

one is expected to be impressed with is the superior tensile and elongation results. One has occasionally yielded to the temptation to use such steels for which a very big price has been paid, but they have usually proved no better servants than ordinary material. A large majority of engineers rest content with tension tests alone, no matter to what use they are putting the steel — some, perhaps, because it is rather an expensive test, taking into consideration cost of plant, etc. It is sometimes stated, consequently, that an ordinary mild steel — say "Admiralty" grade — is not good for certain purposes, but that a particular "special" steel is perfectly safe, etc., because the elastic limit and tensile strength are somewhat better.

A similar assertion is made in the sixth report to the Alloys Committee in reference to heat-treated steel for guns. How much is this tensile strength and elastic limit thereby raised? The answer is, Anything from about 5 to 30 per cent.

The following are the tests that can be made on most pieces of metal, steel in particular: (1) Tension and elongation; (2) compression; (3) cross bending; (4) hammering out to a point or thin edge; (5) fatigue by gradual reversal of stress either by bending in one plane or by rotation, as adopted by Wöhler, Professor Ewing, and others; (6) the same, but with the stress uniformly distributed over the section, as suggested by Prof. Osborne Reynolds; (7) impact on unnotched bars; (8) impact on notched bars; (9) chemical analysis; (10) micro-analysis. There may be variations of the above.

The general uses of steel may be divided into three main groups: (*a*) Structural work subject to steady loads only, such as boilers, buildings, tanks, etc.; (*b*) structural work subject to recurrent loads of one kind, at intervals, in addition to the load due to its own weight, such as bridges, etc.; (*c*) structures subject to rapidly repeated loads of one kind, all more or less suddenly applied, as with bolts and studs, rails, etc.; (*d*) structures subject to alternating loads, such as in the fixed and moving parts of machinery in general, and in many parts of a ship.

For the first two there is no doubt that the tension test is a good and sufficient one, as the predominant stress is certainly pure static tension, but it will be insufficient for the very heterogeneous groups (*c*) and (*d*). The question may then be asked,

Which of the tests in the above long list is really a true universal gauge of the suitability of a piece of steel for any purpose it may be put to? As a help to answer this question, attention may be drawn to the following analysis of stresses in the steel parts of an up-to-date steam engine of moderate size:

	Per cent
Constant tension	3.91
Constant tension and compression $\left(\text{range } \frac{0}{\text{max.}}\right)$	1.30
Constant tension and shock	48.80
Alternating tension and compression with shock	2.81
Repeated tension (from a constant to max.) with shock	36.00
Miscellaneous and doubtful	7.17
	100.00

It will be seen that 87.6 per cent of the whole engine is subject to more or less shock, while pure tension forms an insignificant percentage of the total stress; vibratory or alternating stress, where the transition from one kind to another is gradual (say, following a sine law), and unaccompanied by shock, does not occur at all in normal conditions, although it may be conceded that, under ideal conditions, in the crank shaft, for instance, it will occur. This is in only one machine. If, however, various other machines are examined, it will be found that nine out of ten are working under similar conditions.

Referring to the steam engine, there are important parts, such as piston-rods and connecting-rods, that, under ideal conditions of working, are subject mainly to direct alternating stresses. When, in the majority of cases, a piston-rod gives way, it breaks at the end through the line AB, Fig. 4, and not through the smallest area CD, supposing that happens to be less than the area at the bottom of the thread. In fact, it is dislocated through a section where the effect of repeated blows can accumulate. There is, undoubtedly, in addition to the suddenly applied steam loads, a series of true though comparatively minute blows, with proper adjustment, arising from the necessary slackness in all the bearings.

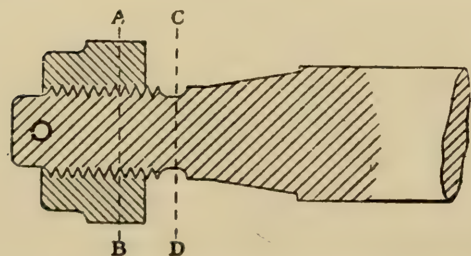


FIG. 4. Fracture of Piston-Rods

The question may be asked, Why do not this rod and similar pieces of machinery break in the same place by the accumulated effect of stress reversals or variations, just as well as with a series of blows? It may be possible that they do so in some instances, but there are a few considerations which incline the authors to the opinion that this is not the case as a general rule.

Fig. 5 is taken from a paper by Prof. J. H. Smith, read before the Royal Society.* Some of the members may have

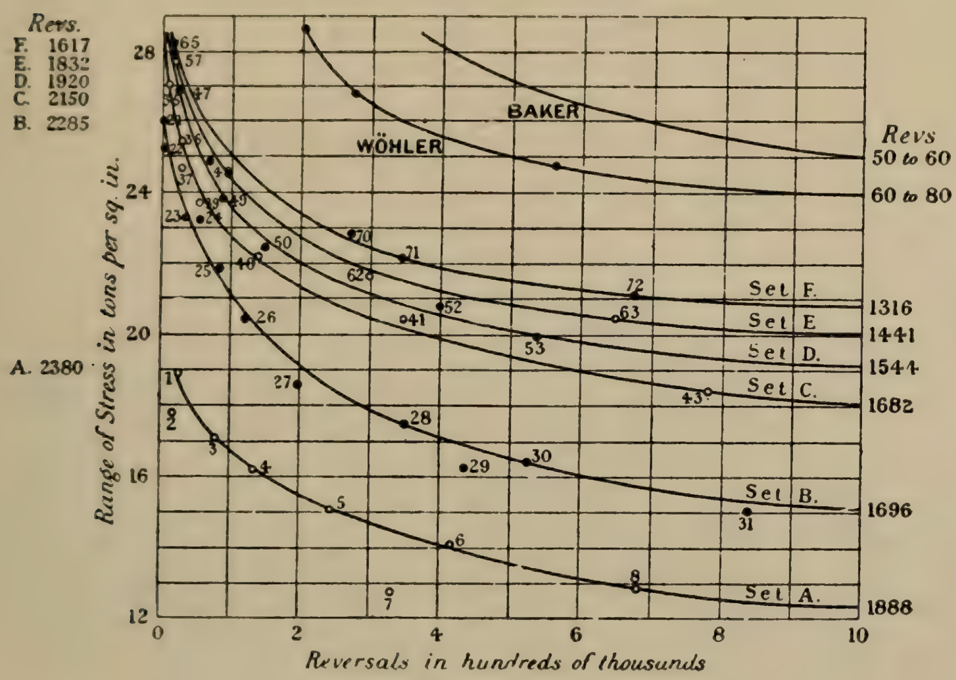


FIG. 5. Mild Steel (Forged)

already seen it. The authors are indebted to Professor Smith for its reproduction. The experiments on which this diagram was based were not made in the Wöhler fashion and as adopted by Mr. Stead, Professor Ewing and others, where reversal of stress is obtained by means of a rotation. Here the stresses were pure tension and compression distributed uniformly over the section, and not as in their experiments, with the maximum stresses at the surface. The variation of stress practically followed the sine law.

* " Proceedings," Royal Society, 1902, Vol. 199, page 265.

There are also exhibited portions of some broken studs in which the working stress probably never exceeded $2\frac{3}{4}$ tons, and

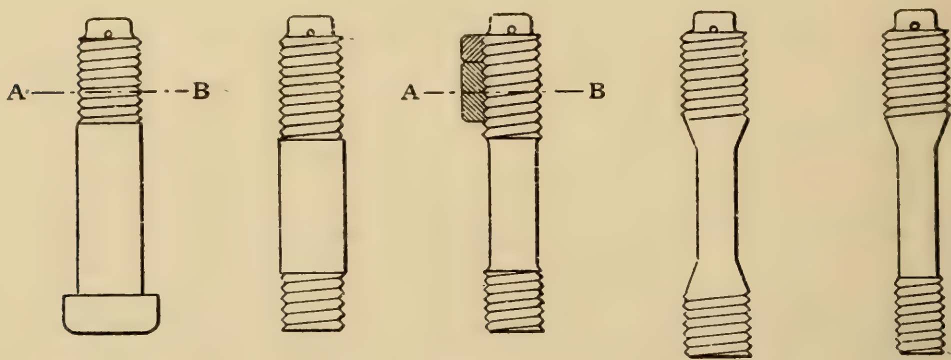


FIG. 6. Fracture of Studs

certainly could not by the most extreme method of calculation have exceeded $4\frac{3}{4}$ tons per square inch. Some examples are shown in Fig. 6, and to which the same remarks apply. The stress given above is the maximum, and the variation of stress was from the initial "nip-up" to this value. In no case did the rate of variation exceed 350 per minute, and the stresses were in all cases variable — that is, of the same sign — and not alternating from + to —. The curves in Fig. 5 alone show that with a range of stress anything below about $11\frac{1}{2}$ tons per square inch, and with 1,880 reversals per minute, it is impossible to break such a steel bar. The total number of variations in six particular cases at the broken studs was as follows:

A	3,200,000
B	7,000,000
C	1,240,000
D	2,800,000
E	5,700,000
F	15,400,000

which represents, after all, only a short life of a few days in the case of some modern engines. From consideration of the relative speeds at which the variations were made, and the limiting condition as determined by the diagram, much more ought it to be impossible to break these studs by the mild "varied stress" treatment actually meted out to them. From the above two considerations it would appear reasonable to conclude that the effect of alternating or variable stresses of the magnitudes determined by the usual factors of safety, and

especially in those cases where the stress is nearly, if not quite, uniform over the whole area — as distinguished from those cases where it varies, as in a beam from o to a maximum at the surface — is quite harmless. Something of a more searching nature must be looked for, and it seems as if it can only be shock — that is, a number of minute blows more or less persistently applied.

There have, no doubt, been many cases where mild steel forgings of this kind have, to all appearances, broken in an unaccountable way. In some cases under the author's notice the shanks of studs have been reduced very considerably, so that the area was only about one half that at the bottom of the thread. Yet without a single exception they all broke through the thread. In fact, some one or two of such studs have had for unavoidable reasons a larger thread at one end than at the other, but they broke through the larger thread and not through the smaller thread. More curious still, in at least three cases under their notice, a complete annular ring has broken between two adjoining threads; and further, these threads rarely break at the ends of the nuts, but in various places, often somewhere in the middle. In the case of those cut up for testing, the usual tensile tests were quite satisfactory, and in one or two where an analysis was taken of the metal close to the fractured surface, it was also quite satisfactory. But on being subjected to an impact test they all gave exceedingly poor results. For instance, —

(A)	broke	after	only	1	blow
(B)	,,	,,	,,	13	blows
(C)	,,	,,	,,	9	,,
(D)	,,	,,	,,	7	,,

From numerous tests it is found that the average impact strength with this particular machine — Fig. 1 — for Admiralty mild steel, ordinary forging quality is equal to about twenty blows. This would be for articles having scantlings of a few pounds. The maximum for the grade and for similar scantlings may be taken at about thirty. Thus, all these test specimens from broken articles gave results considerably below the expected average.

There is yet a third point in favor of the contention that failure is by shock, and not by true alternating or variable

stresses. It is well known that the resistance to alternating stress — rotation method — increases with the carbon content and elastic limit of the steel, but the resistance to shock decreases with an increase in those factors — for "normal" steel.

It has been found in a large number of instances that where fracture has occurred after a few hours' work when using normal medium grade steel — 0.25 to 0.3 C. — this occurrence has been either greatly delayed or indefinitely postponed by the substitution of low-carbon steel, especially when in its best toughened — fine grained — condition. Therefore, apart from the question

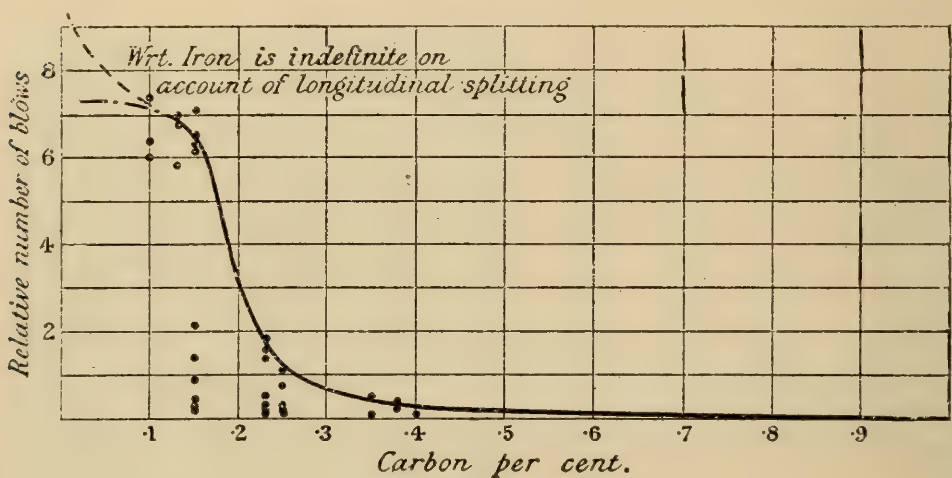


FIG. 7. Curve of Maximum Shock Strength of Commercial "Pearlitic" Steels (Forged or Rolled Quality)

whether even thirty blows given by this particular machine is a good and sufficient insurance against fracture, the point is that it is not satisfactory to subject all steel to one particular test, just because that test may be a suitable one for large quantities of it for one particular purpose. Let there be these particular tests for bridge steel and boiler steel by all means, but steel that will be used for the miscellaneous forgings of machinery in general should be tried by its own crucial tests. Car axles, cranks, and similar articles perhaps should be subjected to an alternating stress by the rotation method, instead of by the shock test, as in their case also the tension test is almost useless as a gauge of the suitability of the material. Professor Ewing and others have shown most conclusively that the resistance to an alternating stress of the kind adopted in their researches

bears no relation to the resistance to pure tension.* There is plenty in each of the aforementioned groups of the uses of steel to warrant different testing methods when necessary.

Reverting to the question, "Is there for groups (*c*) and (*d*) in particular one comprehensive test for steel forgings?" The following appears to be the practical answer: "Simple tension" is not. "Bending" is not sufficient. "Impact" on plain bars is doubtful — certainly too tedious if without distortion. "Reversal of stress" by either method before described is fairly good, but "impact on a notched bar" is best of all; first, because it appears to be a gauge of the preponderant stress. (It is doubtful whether "stress" is the proper term to use; "dislocating agent" would be better, although even this is hardly correct, as will be shown in Part 2.) Secondly, because experience shows that, with absolute certainty, there is always a good enough ductility when there is a good resistance to shock. But it is known equally well that there may be obtained an excellent tension and elongation result from steel which is quite incapable to resist shock. Thirdly, because 99 per cent of all forgings are notched in some way or other, not necessarily with a V nick. Moreover, sharp edges, internal and external, cannot always be avoided in machine design, or even deep scratches in actual construction.

It must not be concluded that the factors of elastic limit, etc., are despised, but since the forces that cause breakage are, in practice, far below the elastic limit in magnitude, and, moreover, as the factor of safety is quite arbitrary and the same in no two pieces of machinery, it seems to the authors that the cart is put before the horse to a great extent. In fact, under the usual conditions of design, one knows enough about the elastic limit, which can only vary in a given grade of steel between comparatively small and insignificant limits, whereas the shock strength can vary almost between infinite limits.

From the very many bars that have been tested by the authors, they have found the number of blows to produce fracture is a fair gauge of the toughness or anti-brittleness. But there is no relation whatever between this result and the tensile results, except what has previously been mentioned, namely, that if the impact result is good, the elongation is sure

* "Journal," Iron and Steel Institute, 1903.

to be good, too; but, on the other hand, a steel showing high tensile strength and good elongation may be useless to resist shock. For example,

		Tension	Elongation	Impact
		Tons per sq. in.	Per cent on 2 in.	Blows
Cold-drawn bar of very low (less than 0.1) carbon steel	(*a*)	31.63	31	1
	(*b*)	31.27	20	180
Low carbon steel (0.15 C.)	(*a*)	28.3	37	175
	(*b*)	27.0	33	5
Medium carbon steel (0.25 C.)	(*a*)	36.5	35	5
	(*b*)	36.5	35	27
Mild cast steel (0.35 C. about)	(*a*)	29.18	22.7	1
	(*b*)	28.25	31	1

Although there is no relation between the tensile-stress test and the alternating-stress test, or between the tensile test and the shock test, the authors are not prepared to say that there is no relation between the alternating-stress test and the shock test. They will, indeed, be glad to learn that there is a close relation, since then the controversial ground as to the nature of the forces, "alternating" or "shock," is at once eliminated. They think it possible that a relation does exist, because, although there are differences in the disturbance of the metal in the vicinity of the fracture, the radical phenomena — "dislocation" and "cleavage" — are the same. A short consideration of these phenomena is given in Part 2.

The majority of steel users require that they shall be able to use an ordinary steel as supplied to them, and without annealing, tempering or other heat treatment. The authors, therefore, urge that the engineer should demand of the steelmaker a greater attention on his part to produce and supply the ordinary grades of steel with a more uniform "shock" quality.

Photographs, thrown on the screen, were used to illustrate the structure of steel. It is, of course, to be expected that brittleness in steel increases with the carbon content, but the authors are convinced that the falling off in this respect is far more rapid than the majority of engineers are aware of. And further, they believe that this has been in a great measure unobserved, owing to the prevalence of the tensile as the only test; and they

are also led to this by the fact that the very toughest "fancy" steels — as distinguished from the natural or normal pearlitic steels — are often produced from what is more or less equivalent to high carbon steels, such, for example, as the nickel alloys, where the ferrite is almost wholly displaced by a composite mixture.

The authors have come to the conclusion that, given a certain percentage of carbon in steel, (1) it is impossible in any given mass to produce a grain below a certain size and still preserve the eutectic as pearlite; (2) there is a minimum brittleness upon which it is impossible to improve while still retaining the pearlite eutectic; (3) this brittleness increases very rapidly with the increase of carbon, especially at or about the "mild" region.

From the results of numerous experiments, they arrived at the results shown on diagram Fig. 7, which gives approximately relative values of minimum brittleness or maximum toughness under shock. For instance, it may be expected that with articles of approximately the same scantlings and in their pearlitic condition, those having 0.2 per cent carbon will be five times tougher to resist shock than those with 0.3 per cent. This diagram is intended to apply to forged or rolled steel and not steel castings — at any rate, not such as usually supplied. Since in a "saturated" steel the line of fracture is necessarily through pearlite, an exceedingly brittle substance compared with ferrite, the next natural conclusion from this is that the line of fracture will be in all cases through as much pearlite as it possibly can. There also appears to be yet a prevalent idea that fracture of any kind takes place more or less along the crystalline grain junctions.

The series of photographs thrown on the screen showed: First, that in any grade of steel of the range under consideration, the line of fracture does not go through as much pearlite as possible; further, that it distinctly avoids doing so, but really goes through as much ferrite as possible. Secondly, that fracture through the ferrite crystalline junctions is extremely rare, and really is practically always through cleavage planes.

The authors have also observed that the fracture through pearlite is not junctional, that is, between the lumps; neither is it, as a rule, parallel to the laminations, but appears to follow

an erratic course both in saturated and under-saturated steels; in the latter the controlling agent is evidently the ferrite, but in the former the reason is obscure. This, however, is outside the limits of the paper in view of the above two statements,

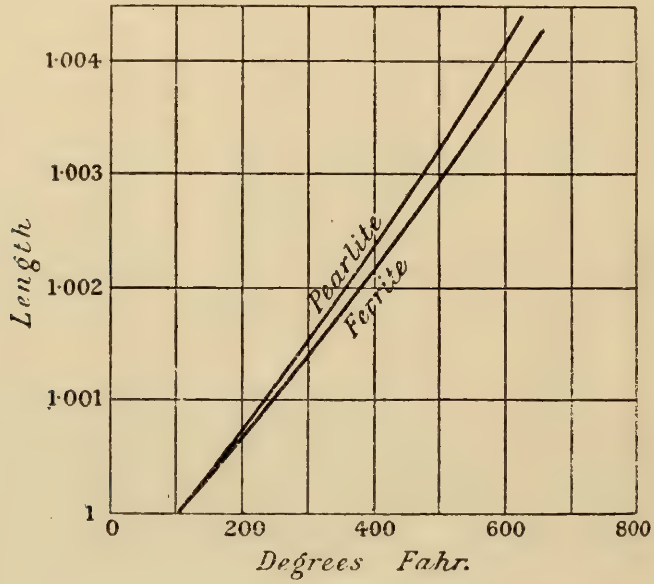


FIG. 8. Expansion (Linear) of Pearlite and Ferrite

but it adds weight to the appreciation of the obstinate action of pearlite. It will thus be seen that by the first statement above there is a contradiction to the second natural conclusion arrived at above, that fracture would of necessity take place through a maximum of pearlite. There is also an apparent contradiction to the first natural conclusion that increased brittleness is the outcome of an increase in the quantity of pearlite. To this latter it is obvious, of course, that there is no real contradiction, seeing that carbon is the only variant.

The distinction between fracture by true alternating stress and by shock is not quite clear in sections taken from the interior of the article. Since there is little or no drawing out of the crystalline grains, it follows that separation by consecutive or progressive slipping will not be nearly so drastic as in the case of the tension specimen. It should, therefore, be much more difficult to obtain a slip-band appearance by etching a specimen broken by an alternating stress considerably below the electric limit. Nevertheless, on comparing the two specimens, it appears that the fracture by alternating stress is accom-

panied by small cracks and fissures in its immediate vicinity to a much greater extent than is the case with the fracture by shock. Further, slip bands — or minute parallel fissures — are often visible close to the edge of the alternating fracture, but they have never been discovered near a shock fracture.

In general, therefore, the remarks in this connection apply to test specimens. The authors have, as has been seen, plenty of articles broken by what they believe to be shock, and there appears to be a perfect identity between the microscopic appearance of the fracture of these articles and their test bars broken by shock.

The results are summarized as follows: (1) Impact test-bar fracture is through ferrite, and has no slip bands; (2) fractured bolts, etc., show no drawing out or slip bands; (3) alternating stress — rotating — test-bar fracture is through ferrite, with external slip bands in profusion, and internal slip bands sometimes visible, but there is no drawing out of crystals; (4) tension test-bar fracture is accompanied by slip bands in profusion, and with the crystals very drawn out; (5) (from Part I) fracture by direct intermittent stress is highly improbable. The only conclusion that seems possible from the above is that the fracture and method of producing the fracture is of a similar nature in the articles that break mysteriously and in the impact test bars broken by a number of blows, that is, by a spreading crack.

The authors having conceded the admitted existence of three critical temperatures, say of the sectional period, it is highly probable that there are changes of volume of the components that take place simultaneously with the chemical or allotropic changes, whichever may occur; but the range of temperature is small and the volumetric changes of the components will be sudden, so that either there will be approximate mutual action or else gaps will be formed. The former seems to be the more probable, as there is no evidence of any gaps under the microscope, and their existence is not confirmed by any of the peculiar ways steel fractures under various forces. Further, the phenomenon of expansion during plasticization at the higher temperatures may be present in the carbon-laden components at their lower plasticization temperatures. But between the first and cold there is a very long period when

the pearlite is constantly contracting at a different rate from the ferrite.

Supposing that the authors' relative coefficients of expansion — Fig. 8 — are correct, then, since the pearlite is contracting at a greater rate than the ferrite, it means that it is acting as a sort of hydraulic expander to the ferrite instead of a hydraulic press, and this effect will increase with the increase of carbon. There would, therefore, be an increasing tendency to hollowness in each individual ferrite grain in much the same way that a piece of lead, for example, sinks down when cooling, and with this tendency they think it is quite reasonable to suppose that there is a corresponding tendency to easy separation through the grain, either individually or in series. And in the case of the higher carbon steels, where the quantity of ferrite is small, there would alternatively be an increasing tendency to separation between the ferrite and pearlite.

A deduction is therefore arrived at that harmonizes the apparently anomalous facts that the line of fracture avoids going through pearlite; that the line of fracture avoids going through the junctions; and that brittleness increases with the carbon content. And, further, the larger the crystalline grains the greater the weakness, which is not only confirmed by their numerous test bars examined, but by the intensely brittle results that are produced by long annealing. Supposing that the coefficient of expansion of ferrite be greater than that of pearlite, there would still be the tendency to openness in the ferrite, but it would be a decreasing tendency with the increase of carbon. On the whole, therefore, the authors think their experiments and observations are confirmatory.

In the foregoing, the subject-matter has been strictly confined to the strength, etc., of steel in its natural condition, or that condition produced by the comparatively slow cooling process of ordinary manufacture. The shock strength of "treated" steels, however, is a matter of equal, if not greater, importance. "Treated" means any process whereby the steel is left in a more or less artificial condition as distinguished from the natural condition just discussed, such as oil-hardening, water-hardening, tempering and allied processes. The authors have not had the time nor facilities for conducting a complete series of experiments with these steels, but they have done

quite sufficient to be assured of the fact that the shock strength of oil-quenched mild steels particularly is not increased a mere matter of 20 per cent (720° C. in oil, 0.25% C.) to 130 per cent (1200° C. in water), as is the case with the tensile strength, but on an average 500 to 600 per cent more than the shock strength of the natural steel in its best condition. Moreover, oil-quenching appears to possess the highly important property of "levelling up" the shock strength of steel to a fairly constant value.

Thus there may be two similar articles made of the same grade of steel, the one coarse and brittle and the other fine and tough, and possessing a maximum shock strength. Oil-quenching will increase the strength of both to a common value, the increase in the one case being, perhaps, several thousands per cent, and in the other, the 500 or 600 per cent above referred to.

They think that practice with such things as gun barrels shows this also very clearly, and they have no hesitation in saying that whereas the tensile testing machines practically make no distinction between the steel that is utterly unfit and that which is eminently fit for the parts of a machine subject to shock or vibratory stresses, the drop-testing apparatus does most certainly, and without fail, make the discrimination, and further, that wherever the drop-testing machine shows a steel to be good, the tensile-testing machine corroborates it. Therefore, it may be concluded that while the drop-testing machine is a certain and reliable guide to the maker of such structures, it is equally the friend of the construction of other structures, subject only to tension or compression steadily or constantly applied.

Attention is particularly drawn to the shock strength of bright rolled bar. It is a remarkable fact that, until quite recently, all the bright bar on the market, with the exception of about two British makes, appeared to be quite rotten under shock, snapping off in all cases with only two or three blows, and not improving very much by oil-quenching. The authors have not had occasion to obtain analyses of the numerous samples of bright bar they have tested, but in the majority of cases the carbon content was stated to be from 0.11 to 0.15 per cent.

In those samples which met in other respects the Admiralty specification, the shock strength was worse than that of lower grades. The reason for the generally inferior results may be

due to the drastic rolling process, but the fact remains that good bars can be produced with certainty by a few makers. They are, however, glad to observe that other makers are rising to the occasion, and that improvement is rapidly being effected, and without the accompaniment of a prohibitive price. They would, nevertheless, recommend due caution on the part of those using the larger sizes of bright bar for important parts of machinery. The number of blows that good bright bar will stand appears to be about the same as for ordinary bar of the same grade.

THE STEEL HARDENING METALS *

THERE are included, under the head of steel-hardening metals, nickel and cobalt, chromium, tungsten, molybdenum, vanadium, titanium and uranium, which are named in the order of the importance of their production and use for steel-hardening purposes. These metals are not added to the steel to cause chemical reactions to take place, by which harmful ingredients are made to go into the slag or to pass off as gases, as is the case in the use of ferrosilicon or ferromanganese (spiegeleisen) which are added to the furnace in the original manufacture of the steel. These other ferro alloys are not added until after the steel has been manufactured, and their use is as a physical addition to the manufactured steel for the physical benefits that they confer upon it, and hence they accomplish their purpose in a manner entirely different from that of the ferrosilicon or ferromanganese.

Some of the metals, as nickel, chromium and tungsten, are now entirely beyond the experimental stage and are well established in the commercial world as definite steel-hardening metals, and new uses are being constantly devised for the different steels, which are causing a constant increase in their production. Others, as molybdenum and vanadium, although they have been proved to give certain positive values to steel,

* The Bulletin of the American Iron and Steel Association, Dec. 10, 1904.

† Extracts from a valuable report by Joseph Hyde Pratt for the United States Geological Survey.

have not been utilized to any large extent as yet in the manufacture of molybdenum or vanadium steel, partly on account of the high cost of the ores containing these metals. Titanium and uranium are still in the experimental stage; and, although a good deal has been written as to the value of titanium as an alloy with steel, there is at the present time very little if any of it used in the manufacture of a commercial steel.

Since the introduction of the electric furnace and the consequent methods that have been devised for reducing ores, it has become possible to obtain these ferro alloys directly from the ores by reducing them in the electric furnace, and hence experiments have been conducted on a much larger scale than formerly.

The prices of the various ferro alloys vary considerably. Ferrochrome in December, 1903, was quoted at $120 to $225 per ton of 2,240 pounds; cost, insurance and freight, New York, on the basis of 60 per cent, with variations up and down at $1.75 per unit. Ferrotungsten was quoted at 40 cents per pound, or $896 per ton, on 100 per cent, cost, insurance and freight, New York. Ferromolybdenum was quoted from $1.50 to $2.50 per pound, or $3,360 to $5,600 per ton, on 100 per cent, cost, insurance and freight, New York; in May, 1904, this had dropped to $1.25 per pound on 100 per cent, cost, insurance and freight, New York. Ferrovanadium was quoted at $7.50 per pound, or $16,800 per ton, on 100 per cent, in the English market, and $6.40 per pound in the French market; for ton lots the price has been quoted as low as $4.50 per pound. Ferromanganese has, during the last two or three years, been very steady, and on contract, 100-ton lots and over, was quoted at $50 per ton, duty paid, with freight paid east of the Mississippi River. In May, 1904, this price had dropped to $44 per ton. Ferro-nickel alloy and metallic nickel vary from 50 to 56 cents per pound for the nickel content.

Besides the use of ferromanganese for the chemical effect which it produces in the manufacture of steel in eliminating injurious substances, it is also used in the production of a special steel which possesses to a considerable degree combined hardness and toughness. Such steel contains from 0.8 to 1¼ per cent of carbon and about 12 per cent of manganese, and is known as "Hadfield manganese steel." If only 1.5 per cent of manganese

is added, the steel is very brittle, and the further addition increases this brittleness until the quantity of manganese has reached 4 to 5.5 per cent, when the steel can be pulverized under the hammer. With a further increase, however, of the quantity of manganese, the steel becomes ductile and very hard, reaching its maximum degree of these qualities with 12 per cent of manganese. The ductility of the steel is brought out by sudden cooling, a process the opposite of that used for carbon steel. These properties of manganese steel make it especially adapted for use in the manufacture of rock-crushing machinery, safes and mine car wheels.

Nickel finds its largest use in the manufacture of special nickel and nickel-chromium steels, and the use of these steels for various purposes in the arts is constantly increasing. The greatest quantity of nickel steel is used in the manufacture of armor plate, either with or without the addition of chromium. There is probably no armor or protective-deck plate made which does not contain from 3 up to 5 per cent of nickel. Nickel steel is also used for the manufacture of ammunition hoists, communication tubes and turrets on battleships, and for gun shields and armor.

The properties of nickel steel, or nickel-chromium steel that make it especially adapted for these purposes are its hardness and great tensile strength, combined with great ductility and a very high limit of elasticity. One of the strongest points in favor of a nickel-steel armor plate is that when it is perforated by a projectile it does not crack. The Krupp steel, which represents in composition about the universal armor-plate steel, contains, approximately, 3.5 per cent of nickel, 1.5 per cent of chromium and 0.25 per cent of carbon.

Another use for nickel steel that is gradually increasing is the manufacture of nickel-steel rails. During 1903 there were over 11,000 tons of these rails manufactured, which were used by the Pennsylvania, the Baltimore & Ohio, the New York Central, the Bessemer & Lake Erie, the Erie, and the Chesapeake & Ohio railroads. These orders for nickel-steel rails resulted from the comparison of nickel-steel and carbon-steel rails in their resistance to wear during the five-months' trial of the nickel-steel rails that were used on the horseshoe curve of the Pennsylvania Railroad. The advantages that are claimed

for the nickel-steel rail are its increased resistance to abrasion and its higher elastic limit, which increases the value of the rail as a girder. On sharp curves it has been estimated that a nickel-steel rail will outlast four ordinary rails.

Nickel steel has also been largely adopted for forgings in large engines, particularly marine engines, and it is understood that this is now the standard material for this purpose in the United States Navy. There is a very great variety of these forgings and drop forgings which include the axles and certain other parts of automobiles, shafting and crank shafts for government and merchant-marine engines and stationary engines, for locomotive forgings, the last including axles, connecting rods, piston rods, crank pins, link pins and pedestal cap bolts, and for sea-water pumps.

Another important application that is being tried with nickel steel is the manufacture of wire cables, and during the last year such cables have been made by the American Steel and Wire Company, but no comparison can as yet be made between them and the ordinary carbon-steel cables with respect to their wearing qualities. In the manufacture of electrical apparatus nickel steel is beginning to be used in considerable quantity. The properties of this steel which make it especially valuable for such uses are, first, its high tensile strength and elastic limit, and second, its high permeability at high inductions. For rock drills and other rock-working machinery nickel steel is used in the manufacture of the forgings, which are subjected to repeated and violent shocks. The nickel content of the steel used in these forgings is approximately 3 per cent, with about 0.40 per cent of carbon. The rock drills or bits are made for the most part of ordinary crucible cast steel which has been hardened and tempered. A nickel-chrome steel is now being made, which is used to some extent in the manufacture of tools.

Nickel steel in the form of wire has been used quite extensively and for many purposes — for wet mines, torpedo-defense netting, electric-lamp wire, umbrella wire, corset wire, etc., — where a non-corrosive wire is especially desired. When a low coefficient of expansion is desired — as in the manufacture of armored glass, in the mounting of lenses, mirrors, level tubes, balances for clocks, weighing machines, etc., — nickel steel gives good satisfaction. For special springs, both in the form

of wire and flats, a high carbon nickel steel has been introduced to a considerable extent. Nickel steel is also being used in the manufacture of dies and shoes for stamp mills, for cutlery, tableware, harness mountings, etc.

Nickel steels containing from 25 to 30 per cent nickel are used abroad to some considerable extent for boiler and condenser tubes and are now being introduced into this country. The striking characteristic of these steels is their resistance to corrosion, either by fresh, salt or acid waters, by heat and by superheated steam. In addition to marine boilers, high nickel-steel tubes can be used to advantage for stationary boilers, automobile boilers and locomotive safe ends.

The largest use of chromium is in the manufacture of a ferrochromium alloy which is used in the manufacture of chrome steel. In the manufacture of armor plate ferrochrome plays a very important part, and, although it is sometimes used alone for giving hardness and toughness to the armor plate, it is more commonly used in combination with nickel, making a nickel-chromium steel armor plate. Other uses of chrome steel are in connection with five-ply welded chrome steel and iron plates for burglar-proof vaults, safes, etc., and for castings that are to be subjected to unusually severe service, such as battery shoes and dies, wearing plates for stone crushers, etc. A higher chromium steel which is free from manganese will resist oxidation and the corrosive action of steam, fire, water, etc., to a considerable extent, and these properties make it valuable in the manufacture of boiler tubes. Chromium steel is also used to some extent as a tool steel, but for high-speed tools it is being largely replaced by tungsten steel, which seems to be especially adapted to this purpose.

Ferrochromium is made in an electric furnace and is produced directly from the ore. In the United States the company producing the largest quantity of ferrochromium is the Willson Aluminum Company, whose electric furnaces are located at Kanawha Falls, W. Va. Besides the manufacture of ferrochromium this company also makes ferrotungsten, ferromolybdenum, ferrosilicon, ferrovanadium and ferrotitanium. The company obtains its chief supply of chrome ores from the Daghardi mines, in Asia Minor, and the Thiebargi mines in New Caledonia. Ferrochromium has also been made by the Willson

Aluminum Company from the chromium ores from the Black Lake district, Quebec Province, Canada.

The Willson Aluminum Company has been supplying the ferrochromium used by the Bethlehem and the Carnegie steel companies for the armor plates which these companies have manufactured.

The demand for tungsten ores for use in the manufacture of ferrotungsten to be used in the manufacture of tungsten steel continues to increase, especially from abroad. Tungsten steel is used to some extent, more generally abroad than in the United States, in the manufacture of armor plate and armor-piercing projectiles. For this purpose it is used in combination either with nickel or chromium, or with both of these metals. The use for which tungsten steel seems to be best adapted is in the manufacture of high-speed tools and magnet steels. There is considerable variation of opinion as to the value of tungsten in the manufacture of armor plate.

The use of molybdenum steel continues to increase, and hence there is an increasing demand for the ores of this metal. The main use of ferromolybdenum is in the manufacture of tool steel.

ELASTICITY AND STRENGTH *

THERE is a well-known story of a country magistrate who protested against his clerk not allowing him to decide a case immediately on the completion of the evidence for the plaintiff, since all further testimony, he found, merely served to complicate a case which up to that point was perfectly straightforward and clear. In regard to the important question of the strength and elasticity of structural materials, many engineers must, we imagine, have a good deal of sympathy for the unfortunate victim to legal custom just referred to. The earlier experiments showed steel and iron to be perfectly elastic bodies within certain limits, and on this assumption the determination of working stresses appeared a perfectly simple matter. Evidently, if a body completely recovered its original form on

* "Engineering," October 7, 1904.

the removal of a stress deforming it, no damage could be done to it by a load producing a stress less than the elastic limit, and a rational basis for proportioning the parts of a structure or a machine was immediately available. No sooner had this happy condition of affairs been reached than further testimony was offered which, to quote the rural Rhadamanthus above mentioned, has only served to complicate matters. Practical men like Sir William Fairbairn maintained that a live load was twice as dangerous to a structure as a dead load of equal intensity, and proved it by experiments on a plate girder. This fact found a ready explanation in a possible increase of stress due to "impact," but here again the further evidence afforded by the experiments of the railway commissioners quite upset this explanation, though it is only fair to state that it is not dead yet, as many engineers, with imperfect appliances, have recorded enormous impact strains in members of bridges traversed by a rolling load. M. Rabut has, however, shown that the effects observed were in the main due to defects in the apparatus, and has proved, by using instruments of the "dead-beat" type, that the impact effects on large bridges are insignificant, and are nothing extraordinary even in cross-girders and longitudinals. Previous to this, Wöhler had, in his experiments on repetition of stress, shown that the "fatigue" of metals was not a figment of the imagination, as had been suggested; and Bauschinger, by his experiments on the elastic range of materials, had done much towards providing a rational explanation of Wöhler's results. He considered he had detected two true elastic limits in steel specimens, viz., a compression limit and a tension limit, the latter being quite different from the yield point, which is in commercial testing assumed to be the same as the elastic limit. Moreover, he found that if the tension elastic limit of a bar was raised by over-straining, the compressive limit was lowered to a corresponding degree, so that, roughly speaking, the elastic range of a bar was constant, and, further, was about equal to the range of stress through which a bar could be repeatedly strained without fracture.

These observations seemed to accord very well with practical experience in the use of steel. It was well known that in practice hard steels withstood vibratory stresses much better than milder ones. Thus, Mr. C. B. Dudley has stated that

the substitution of an 80,000-lb. steel for one of 65,000-lb. tensile strength in car-axles on the Pennsylvania Railroad quite got rid of the trouble from breakages, which, with the mild steel, were frequent after a life of two years. The calculated stress at the point of failure was, it should be observed, only 6,700 lbs. per square inch, corresponding to a range of 13,400 lbs. Possibly the presence of a shoulder may have caused the actual stress to be greater than that calculated, but on this point we have no information. On Bauschinger's theory the difference between the two steels is quite intelligible. The harder steel has a greater elastic range, and hence a greater endurance for the same limits of stress than the softer steel.

At this point, however, new complications were introduced by experiments carried out by Prof. Osborne Reynolds and Mr. J. H. Smith on bars broken by alternating stresses, which led them to the conclusion that if the repetitions of stress took place with sufficient rapidity, there was no great difference in the endurance of hard and mild steels. This conclusion is the more remarkable in that the periodicity of the stress was nothing exceptional, the highest rate reached being 2,500 cycles per minute. Moreover, somewhat similar experiments made by Mr. William Metcalf in 1877, in which quite high rates of repetition were reached, showed the harder steels to be much superior in endurance to the softer varieties. In these experiments small connecting-rods were caused to reciprocate at the rate of 1,200 revolutions per minute, the inertia stresses being such that a rod of steel containing 0.3 per cent of carbon broke in 1 hour, 21 minutes; one of 0.43 per cent carbon ran 4 hours, 57 minutes; and one of 0.84 per cent carbon ran 18 hours. Eight rods of different carbon content were tested, and the results were not quite regular; but the general trend of the experiments is represented by the specimen results just quoted. For the moment, therefore, the point remains in abeyance, but should be cleared up by the experiments now in progress at the National Physical Laboratory.

There is, perhaps, nothing inherently improbable in the endurance of a test-bar being a function of the periodicity of the loading. Professor Bouasse, of Toulouse, who has spent many years in studying the behavior of solids exposed to varying stresses, claims that no such thing as an elastic limit

exists, and that no body deforms in accordance with Hooke's law, the two concepts being merely rough approximations to the actual facts of the case. All bodies, he asserts, exhibit the phenomenon of hysteresis at all ranges of stress if examined with sufficient care. Thus, if a long wire is loaded and its load removed, it immediately recovers its original length very nearly, but not quite, the residual stretch only disappearing when the wire has been left unloaded for a sufficient time. Given time, it will entirely recover its original dimensions, provided the load applied has not been too great; but from this it follows that strain is not directly proportional to stress, but is a time function thereof.

In a paper presented a few months ago to the Manchester Literary and Philosophical Society, Mr. Frank Foster endeavors to account for the fatigue of metals by taking into consideration this hysteresis. His theory is that on the completion of the first cycle of loading there is, owing to hysteresis, a residual strain, and that at the end of the second cycle this residual strain is increased by fresh hysteresis, so that the amount of residual strain continues to augment with each repetition of the load until failure finally occurs. At high stresses something of the sort probably does take place, since Professor Ewing and Mr. Humfrey have observed that under the microscope a steel bar, subjected to alternating stresses sufficient ultimately to fracture it, gradually develops the "surfaces of slip" between the different crystals characteristic of a bar strained under steady load beyond its elastic limit. Whether, however, there is a point below which such hysteresis as exists has no cumulative effect on the strain is another matter.

Some light on the point is, perhaps, to be found in the experience of chronometer-makers. It appears that whilst mainsprings break not infrequently, balance springs last indefinitely. Cases of twenty-five years' service are on record, and they have been known to run continuously for nine years, though so long a run is very bad for the other moving parts, which, if kept at work too long without cleaning, begin to cut. The periodicity is commonly two cycles of stress per second, so that, making a certain allowance for idle time for cleaning and repairs, a spring twenty-five years old will have passed through some 1,500 million cycles of stress. Through the cour-

tesy of Messrs. S. Smith & Son, of 9 Strand, we have been able to make an estimate of the range of stress on these springs, which are now made of tempered steel. The springs are helices, measuring 0.50 inch in mean diameter. The wire, which is flattened, is 0.012 inch thick, and there are 10.75 coils to the spring. The extreme range of vibration is about $\frac{5}{4}\pi$; and from these data the range of stress is readily calculated as about $18\frac{3}{4}$ tons per square inch.

This it will be seen is quite a low range, considering the quality of the steel, yet we are informed that untempered springs will not stand even this moderate range, but will break after a more or less prolonged service. The maximum stress is $9\frac{3}{8}$ tons per square inch, and is, of course, alternately a tension and compression. In governor springs Mr. Hartnell finds a working shearing stress of about 30 tons permissible, but the range of stress is here unknown, and certainly the variations in stress have nothing like the range and constancy of those in a balance spring.

In spite of their moderate range of stress, these balance springs show some very curious hysteresis effects. It takes them about a year to settle down to a steady rate, the stiffness continuing to increase for about this period after the chronometer is started. At the end of that time they settle down to practically perfect isochronism, which is maintained so long as the chronometer is kept going. If, however, the instrument is stopped for cleaning or repairs, the spring again requires time to attain its former rate of vibration, so that the stoppage which is necessary to keep pivots and gearing in order is, it appears, a bad thing for the spring. It would seem from the foregoing that once the spring has attained its steady rate, there is no growth of residual strain; but it is very remarkable how low the working stress has to be kept to attain this end. For all practical purposes the spring, in the conditions stated, acts as a perfectly elastic body. It has, however, to be admitted that the periodicity is low, and that at higher rates it is quite possible a reduction in the range of working stresses would be necessary if breakage were to be avoided. This point is still an open one, and can only be settled by further experiment.

From a practical point of view, it is to be hoped that such experiments may prove that the possible range of working

stresses is really independent of the periodicity, since matters are quite sufficiently complicated already, and the designer will by no means welcome the task of considering not only the magnitude and range of his stresses, as he does at present, but that of also taking into account the frequency with which these stresses vary.

THE DETERMINATION OF SULPHUR IN STEEL BY EVOLUTION METHODS *

By GEORGE AUCHY

ALTHOUGH it is a matter of common knowledge that in pig irons containing much combined carbon evolution methods fail to get all the sulphur on account of some of it combining with the carbon, yet the belief is equally widespread that in the case of high carbon steels the reverse of this is true, and the sulphur is completely evolved as sulphureted hydrogen, and evolution methods are therefore held to be accurate for high carbon steels, though not for pig irons of the same percentage of combined carbon. It is true that it is the almost universal practice of steel works laboratories in the West to standardize their iodine solutions by a standard steel, yet as far as the writer can judge, this is done simply as a matter of convenience, and not with any idea of counteracting any error that might result from loss of sulphur as mercaptan compound. But in spite of the very general belief in the accuracy of evolution methods for high carbon steels, the writer's experience compels him to the opposite belief, and he begs to give some results which, if accurate, justify the conviction that in high carbon steels there is just as much loss of sulphur in evolution methods as there is in pig irons by such methods. Of the aqua regia results that he has obtained, only those are given in the following table which were obtained with a blank or dummy test on a nearly carbonless low sulphur Swedish iron, in which the sulphur (0.004 per cent) had been repeatedly determined by evolution instead of a blank on the reagents simply. The determinations were made in sets of three with a blank test to each

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* "The Iron Age," December 29, 1904.

set, as before stated, using the nearly carbonless and sulphurless Swedish iron for the blank:

No.	Carbon Per cent	Sulphur by evolution Per cent	Sulphur by aqua regia Per cent
6,188	1.09	0.037	0.048
6,189	1.12	0.031	0.046
6,190	0.96	0.020	0.038
7,224	1.03	0.029	0.044
6,716	1.24	0.036	0.049
6,944	0.525	0.019	0.025
6,823	0.455	0.030	0.040
6,943	0.525	0.029	0.037
7,221	0.050	0.031	0.039

When the iodine solution is standardized, as is usually done in the West, with the aid of a standard steel, then of course this error is eliminated in such cases where the sample happens to be about the same carbon as the standard steel used in standardizing the iodine solution. But obviously a better and surer method of correcting the error is to find by trial just what loss may be expected in high, medium and low carbon steels, respectively, and then correcting one's results accordingly, using iodine solution standardized in the regular way, and not by means of a standard steel. From the above table it will be seen that 1 per cent carbon steels should have their sulphur results (by evolution) increased at least one third, and 0.50 per cent carbon steels should have their sulphur results increased one fourth. Low carbon steels, of course, need no correction.

The question of course arises that if it be then true that in high carbon steels sulphur is lost by evolution methods, how is it that this fact is not generally known? Surely, the many chemists working on steel have repeatedly tested their results by evolution and checked them by aqua regia tests! The only answer possible to this objection is that there must be some source of error in the aqua regia method for high carbon steels that brings results by that method also too low. That this is in fact the case is indicated in a recent paper by Ford and Willey. The next question then is, What is this source of error in the aqua regia method? While the writer believes that Ford and Willey are correct in their facts, he has to consider that aside from their important point of too quick solution, their effort at explanation (that commercial chemists are not skilled

enough to use the aqua regia method successfully) is rather a feeble one. There must be some chemical reason for the low aqua regia results. Now, if we take the directions given by our greatest authority in iron and steel analysis — Blair — and read them over, we find them at every point to be models of careful precision, except perhaps one, where it is directed that the solution of high carbon steels may be hastened by the use of hydrochloric acid. Right here is perhaps the reason of the low results, and if so it would explain why chemists get correct results in pig irons by aqua regia, and low results in steels. In this laboratory no hydrochloric acid is used in dissolving the steels.

The evolution method commonly in use may be a little simplified and shortened by omitting the large dilution previous to acidification and titration. With the amount of sulphur found in steels, it is entirely unnecessary to dilute largely in order to keep the sulphureted hydrogen in solution, and therefore the absorption apportion may conveniently consist of a Fresenius nitrogen bulb, and the titration may be made without removing the liquid from the nitrogen bulb, but of course in diluted form. But it is essential that the liquid be entirely cold when titrated, as otherwise too high results are obtained.

In the aqua regia method a precaution worth mentioning is to have barium chloride present in large excess in the hydrochloric acid used for washing the barium sulphate.

ABSTRACTS *

(*From recent articles of interest to the Iron and Steel Metallurgist*)

MICROSCOPIC Observations on Naval Accidents. Thomas Andrews. "Engineering," December 2, 9 and 16, 1904. 8,000 w., numerous illustrations. — The author describes an extensive series of experiments conducted in order to ascertain the cause of failure of the steel connecting-rod of the starboard high-pressure engine of H. M. torpedo destroyer *Bullfinch*. The accident occurred on July 21, 1899, and caused the death of eleven men. The author's conclusions are as follows:

1. A consideration of the chemical analyses indicates that the chemical composition, with the exception of the high percentage of silicon, was generally satisfactory, though the author considers the percentage of combined carbon is higher than is desirable for connecting-rod steel, used for such high-speed work, where the vibratory stress is consequently considerable.

For this class of work the author prefers that the maximum of combined carbon should not exceed about 0.30 per cent.

The percentage of silicon is very high, and the author thinks that to some extent this has contributed to micro-crystalline weakness in the physical structure of the mass.

The author thinks, also, that the excess of silicon is to some extent responsible for having increased the needle-shaped brittle crystalline formations in the general mass of the steel, but the thermal or annealing experiments given in this report have shown that this was chiefly due to thermal conditions.

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* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

The percentages of manganese, sulphur, phosphorus and arsenic are satisfactory, and there was no perceptible quantity of copper, chromium or nickel present.

2. Tensile tests were made with generally satisfactory results. The cold bending test also yielded good results.

Compression tests were also made from near the top of the fracture at the root of the fork of the rod, and from other positions, and these tests afforded good indications of the general physical properties of the mass of the steel when under the influence of the slowly applied strain used in this method of testing.

One comparison test was made longitudinally and another transversely, and in both instances the steel was compressed to 50 per cent of the original height of the test-piece. There were no signs of cracking under the effects of this steadily applied pressure, the test-pieces being examined when compressions of 25, 37.5 and 50 per cent had been reached. The results are therefore satisfactory under the conditions of these tests.

The behavior of steel under steadily applied strain does not, however, always afford a criterion of its resistance to sudden shocks or prolonged vibratory concussions.

3. It was noticed that the sides of the interior circumference of the central hole through the connecting-rod bear the marks of the boring or drilling tool in places, as internal transverse scratches or fine circumferential grooves. In such a metal as steel the finest transverse scratch (acting as a diamond cut across glass) is capable of easily developing a transverse flaw under vibratory stress. In view of the acute-angled and acicular ingot-like micro-crystalline structure found in this rod, it is possible that the transverse fracture had been to some extent facilitated by the above cause. Part of the transverse fracture, in fact, was along one of these indentations.

Further confirmation of this is also afforded by the fact that a small fine internal flaw was detected extending transversely for a distance of about $\frac{1}{16}$ inch, adjacent to the hollowed inside of the connecting-rod.

The author considers it desirable, as a future means of prevention, that the interior surface of hollowed forgings should be at least equally smooth bored and polished as the external

surface. This would tend to minimize risk in the case of both steel or iron connecting-rods, which are submitted to high-speed running and rapidly alternating vibratory or other stresses. The micro-crystalline structure of that portion of the connecting-rod submitted for examination near the fracture appeared to have the general appearance of a forging which had been rapidly reduced locally by a somewhat heavy hammer, and which had subsequently received a considerable amount of forging at variable and comparatively low temperatures.

The distortion of micro-crystalline structure sometimes produced by heavy hammering (sometimes at temperatures below the crystallizing point of iron), required to obtain sudden and large local reduction in the mass form of structures, is often detrimental to after-stability in steel forgings. The more gradual such form of reduction can be made, and at as uniform a temperature as possible, the better for the after endurance of the forging. If the hammering has been done with too heavy a stroke, or with a hammer of disproportionate weight to that of the mass of the forging, there will sometimes be developed an axial longitudinal flaw, consequent on the undue crushing in of the material towards the center. Possibly this may, to some extent, have been the case with the present fractured connecting-rod; though without direct evidence this cannot be stated with certainty.

4. The high-power microscopic examinations have helped to throw light on some of the causes of the fracture.

This part of the investigation has shown that the ultimate crystals generally were of somewhat peculiar formation, and that the general micro-crystalline structure was in numerous places of a long, needle-like, spiky and wedge-like character; in fact, more resembling ingot structure than that of finished and annealed forgings. There was also a want of uniform interlocking structure, as between the ferrite and carbide of iron areas of the mass. In fact, many of the carbide of iron areas and ferrite portions of the steel were long, narrow and of wedge-like character, constituting considerable lines of weakness in the general micro-physical structure of the steel.

A reference to the high-power illustrations shows the peculiar acicular nature of the general micro-crystallization of the mass, and the author considers such a crytalline condition is

undesirable for connecting-rod steel. He regards the general type of the crystalline structure of that portion of the connecting-rod adjacent to the fracture as not being the one best calculated to resist either sudden, heavy impact shocks or a prolonged series of lesser vibratory concussional strains.

From the indications afforded by the various high-power microscopic examinations which the author has made, he is tentatively of opinion that this micro-crystalline formation has been induced in the steel in some measure both by the method of manipualtion and the thermal conditions obtaining during the making and finishing of the forging.

He thinks, judging tentatively from the microscopic parts of the investigation, that the finished forging has not been annealed at a desirable temperature. Confirmation of this is afforded by the results of the microscopic experiments on the effects of thermal or annealing treatment on the connecting-rod, in course of which experiments the forging was annealed at a maximum temperature of 950° C. The difference and improvement produced by the annealing on the general crystalline structure of the steel was very marked, and it is clearly demonstrated on comparing the micrographs, which show the more satisfactory interlocking structure as between the ferrite and the carbide areas induced by the annealing treatment. The author would here state, however, that the temperature, 950° C., used in course of these special experiments is somewhat higher than he would generally prefer for most classes of annealing; he considers that a rather lower temperature would in ordinary cases be preferable. The general results obtained in these experiments show the importance of efficient quantitative annealing by pyrometer measurement in order to obtain a satisfactory and reliable crystalline structure for steel forgings.

Microscopic observations were made at a high magnification on the effects of transverse compression stress near the top of the connecting-rod fork. The nature of the crystalline slip observed appeared to be generally normal in its character, though approximating towards rather the micro-crystalline slip of steel ingots when under pressure than to that of finished steel forgings.

5. It is possible that the tendency to local micro-segregation of the carbon contents near the base of the fork of the split

connecting-rod noticed in the microscopic examination may indicate the presence of a local central axial longitudinal segregation in the original ingot, which has ultimately led to the central splitting down of the connecting-rod.

The author has met with similar longitudinal splitting in the center of steel rails, due to local and longitudinal segregation of some of the chemical elements in the primary ingot.

In cases of longitudinal ingot piping, or of central axial segregation of the chemical constituents, there are often found flaw ramifications of varied sizes shooting off transversely; some of these are often minute. It appears as though one of these had been met with in this connecting-rod. A similar transverse development is seen in the illustration of longitudinal axial splitting in the steel rail. If there had been central longitudinal segregation or piping in the rod, it would be cut out when the central hole was bored, so that its presence cannot now be so easily detected; yet some of the finer transverse outer ramifications may have been left.

In view of the fact that some other of the connecting-rods of the engines of the *Bullfinch* had developed longitudinal flaws similar to those found in the broken rod, it would appear as though this set of rods had been made from steel ingots in which central piping had developed to some extent longitudinally.

It would consequently seem as though sufficient had not been cut off from the tops of the ingots to get rid of the adverse effects of the piping. Unless the finest and remotest ramifications of the ingot piping are entirely eliminated, there is always risk of the existence of these longitudinal central flaws in steel forgings or rails, which sometimes dangerously develop under the influence of vibratory or concussional stress.

This the author has demonstrated in his recent investigations on the "Adverse Effects of Segregation on the Strength of Steel Rails" (see Trans. Soc. Engineers, November, 1902).

6. Further, it is a question as to whether the general mechanical construction of the connecting-rod was all that could be desired. Was the general design, apart from the material, a source of weakness? This part of the subject is, however, somewhat outside the scope of the author's present investigation.

A consideration of the tracings of the connecting-rods submitted to the author shows that the general construction

is not an unusual one for machinery of this type; he thinks, however, that from some metallurgical aspects it is capable of improvement.

7. As the result of a careful series of investigations, the author has arrived at the conclusion that the micro-crystalline structure of the fractured connecting-rods examined manifested general characteristics owing, to some extent, to chemical composition, insufficient annealing, or heat treatment, which, he thinks, do not tend to promote reliability or durability. He is also of opinion that it would have been desirable, if possible, to have had a somewhat stronger general constructive design for the rod, in view of the high speed, rapidly alternating stresses and constant vibratory concussional forces involved in the work of the rod.

The author has expressed his views as to the chemical and physical specification of steel connecting-rods in the suggestions he has recently drawn up, from a metallurgical aspect, with the object of obtaining reliability and durability in structural parts of this class. In this research he has striven to demonstrate some of the latent microscopic and thermal causes which apparently lead to accidents of this nature.

The ordinary methods of external examination, chemical analysis and physical tests appeared in this instance insufficient to detect the source of weakness in the mass structure of the steel, which was, however, revealed by the combined microscopic and thermal method of examination. Some intimation has also been given tending to promote future safety in the construction of naval forgings. **No. 283. Each B.**

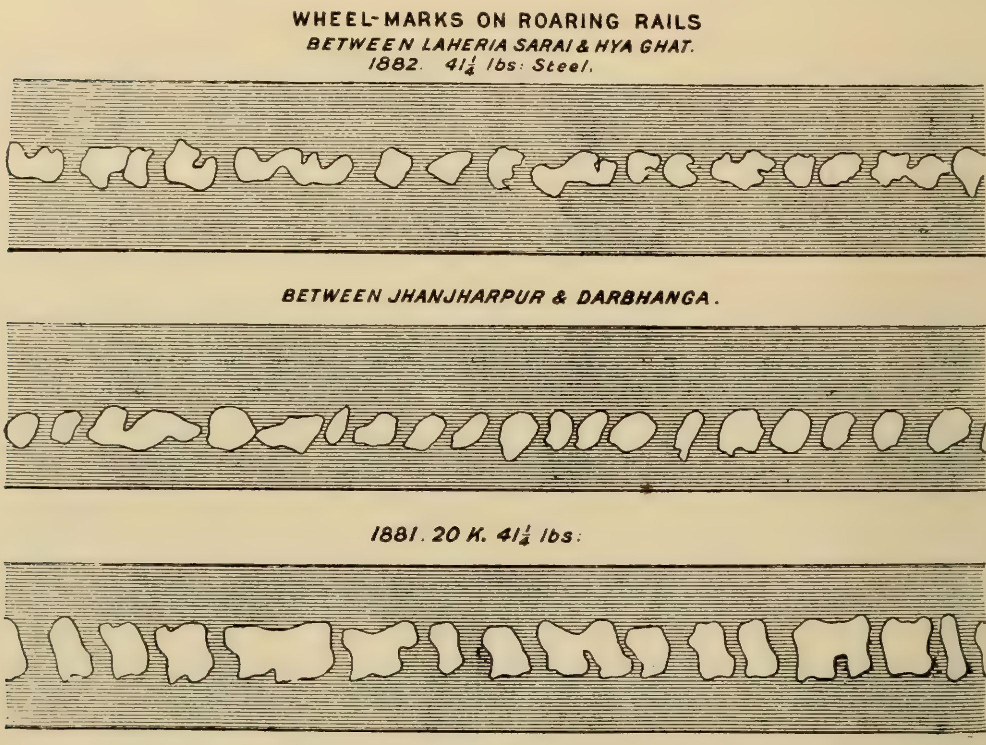
Heat Treatment Experiments with Chrome-Vanadium Steel. Capt. H. Riall Sankey and J. Kent Smith. The Institution of Mechanical Engineers. Paper read December 6, 1904. 48 pages, numerous photomicrographs and other illustrations. — The authors describe some experiments which they conducted to ascertain the properties of chrome-vanadium steel. The steels experimented upon were produced in the open-hearth furnace at the Willans and Robinson's Ferry Works, Flintshire. The principal tests were carried on with steel containing 0.297 per cent carbon, 0.059 per cent silicon, 0.394 per cent manganese, 1.066 per cent chromium and 0.17 per cent vanadium. They

were, as far as possible, a replica of the ones made by the Alloys Research Committee. Attention is called to the high number of alternations endured by the chrome-vanadium steel in Arnold's testing machine, especially by the raw steel, from which it might be argued that these steels will be found suitable in cases of severe shock and sudden variations in stress. A marked change takes place between the temperatures of 690° and 800° C. (no doubt at the Ar_1 point), which in the annealed samples consists in a reduction of elastic limit and tensile strength, a great increase of the impact figure and an increase of ductility. By comparison with a steel of similar carbon content of the report of Alloys Research Committee, it is noted that the chrome-vanadium steel is distinctly less sensitive to heat treatment than the pure carbon steel, and that the impact figure is considerably larger, a fact which is considered of the greatest practical value. It is noted that if the tensile strength is to be maintained the annealing temperature should not exceed 650° C., but that if the best all-around result is required the annealing temperature should be 900° C. Tests with other chrome-vanadium steels are also reported. **No. 284.**

Roaring Rails. H. L. Wilkinson. "The Engineer" (London), December 2, 1904. 1,000 w. — The author describes some experiments which he recently conducted as to the cause of a mysterious complaint which attacks steel rails on many railways, causing the rail surface to be worn, under the action of traffic, into a series of ridges and valleys or corrugations, perceptible to the eye and touch, which produce a deafening noise as the train passes over them.

The illustration shows three samples of marks on the surface of roaring rails, and is reproduced from a tracing by means of a piece of transparent paper and pencil. The uncolored, irregular-shaped figures represent the ridges of the surface of the rail. They appear to the eye as a row of bright polished patches, the rest of the rail surface being dull, showing that the wheel runs over these ridges, and does not touch the rest of the surface. Examination by the hand shows that the bright patches are really raised portions of the surface, with valleys in between. In some cases they stretch across nearly the whole width of the rail table, and appear as corrugations,

but in the majority of cases they are as shown in the tracing, just raised lumps on the general surface. The height of these ridges, or, as some call it, the depth of the corrugations, has been measured and found to average about 0.0035 inch.



ROARING RAILS

The results of the author's experiments point to this wearing being due to excessive hardness, and he concludes as follows:

"It is reasonable, therefore, to look upon this excessive hardness as the chief cause of the defect. This narrows the inquiry, since it only remains to consider what it is that causes the hardness. I feel convinced that it will be found to be an excess of one or two of the elements of phosphorus, sulphur or manganese in the steel." **No. 285. B.**

The Gas Engine in Iron and Steel Works. J. H. Hamilton. "Page's Weekly," December 9, 1904. Abstract of a paper read before the Staffordshire Iron and Steel Institute. 1,000 w., illustrated. — The author considers briefly the economy of the gas engine and describes concisely some modern types of large engines, including the "Crossley," "Premier," "Cockerill,"

"Korting" and "Oechelhauser" engines. He concludes as follows: "For iron and steel makers there is the abiding fact that the gas engine uses their blast-furnace gas direct, and for a given amount furnishes many times as much energy as the steam engine, and that its complete adoption in their works will render it unnecessary to consume fuel anywhere except in the blast-furnaces, and furnish all the increasing power which the newer systems of working demand." **No. 286. B.**

The Sargent Gas Engine. "The Iron Age," December 15, 1904. 1,200 w., illustrated. — The Sargent complete expansion gas engine is distinguished from the more common form of gas engine in that it is double acting and expands the burning charge practically to atmospheric pressure, the point of cut-off being varied with the load as in a steam engine, and the time of ignition advanced as the mixture gets weaker and the inflammation slower. The advantages claimed are increased efficiency, increased regularity in speed and smooth running under early cut-offs.

The Wellman-Seaver-Morgan Company, Cleveland, Ohio, has the exclusive right to manufacture and sell the Sargent complete expansion gas engine, and is prepared to furnish the engine in units from 100 horse-power up, in single cylinder, tandem and twin tandem styles. **No. 287. B.**

Vanadium Steels. L. Guillet. "Comptes Rendus," August 8, 1904. 1,200 w. — The author's further experiments on vanadium steels indicate that the pearlitic alloys (*i. e.*, those of low vanadium content), annealed at 900° C., are no more brittle than carbon steels of equal carbon content. Those with high percentages of vanadium are of particularly irregular structure and strength. This the author attributes to the presence of the light carbide of vanadium, which tends to float when the metal is being cast. He affirms that, differently from the opinion expressed in a former paper, the only vanadium steels of interest are those containing less than 0.7 per cent vanadium. Proceedings of the Faraday Society. **No. 288.**

Persistence of Dendritic Forms in Crystals of Metals. F. Osmond and G. Cartaud. "Comptes Rendus," August 8, 1904.

1,000 w. — The appearance of dendritic crystallites on the polished and etched surfaces of certain metals, particularly bronzes containing 9 to 10 per cent of tin, is generally explained by a non-homogeneous distribution of the tin. Such a distribution is in accordance with the theory of solution, which therefore confirms the accepted explanation. The authors consider, however, that the sharpness of the boundaries of these markings remains to be accounted for, and they point out that certain mechanical causes which come into play during the grinding, polishing and etching of the surface contribute to the observed effect. Tney follow the process of preparing a specimen of a metal containing two constituents of unequal hardness, laying stress upon the different extent to which these constituents will flow or become eroded under the treatment. They arrive at the conclusion that "dendritic crystallites" may appear in a nearly pure metal, where their presence would be due entirely to mechanical actions during polishing. Consequently, the authors describe and recommend a method of successive light polishing alternating with light etching, whereby the formation of an altered surface layer may be practically avoided, or minimized. This method may be extended to metals like lead and tin, which are too soft to be polished in the ordinary way. Proceedings of the Faraday Society. **No. 289**.

Evolution of Structure of Metals. G. Cartaud. "Comptes Rendus," August 16, 1904. 1,000 w. — Etched lead and zinc show a surface structure, a network of nearly straight lines. Alternative etching and polishing gradually remove this, showing a much larger structure beneath. Similarly oriented grains of the original (solidification) structure are covered by similarly oriented networks. The different surface structure is regarded as owing its origin to strain. The junctions in the mass structure take the mean direction of the corresponding but irregular junctions in the cast structure. The frequent double and triple boundaries are, the author thinks, traces of other transition states of equilibrium. In lead which had been strained, and then annealed, either by heating or spontaneously, the boundaries were straight, and no relation between them and the cast structure was visible. Proceedings of the Faraday Society. November, 1904. **No. 290.**

"The Foundry." — The December (1904) issue of "The Foundry" contains the following articles of interest:

"Foundry of H. Bollinckx, Brussels, Belgium."

"Loss in Malleable Foundry." R. F. Flinterman (A. F. A. Convention, June, 1904).

"Successful Brass Founding." J. F. Buchanan (A. F. A. Convention, June, 1904).

"Coal and Coke for Foundry Use." Bradley Stoughton (New York Foundry Foremen's Association, October 1, 1904).

The January (1905) issue includes the following articles:

"Steel Foundry of the Wellman-Seaver-Morgan Engineering Company," Cleveland, Ohio.

"Molding Machines and Their Uses." E. H. Mumford (A. F. A., Indianapolis, June, 1904).

"Molding Machines of To-day." H. M. Ramp (A. F. A., Indianapolis, June, 1904).

"Molding Machine Practice." F. W. Hall.

"By-Product Foundry Coke." Chr. Schwerin (A. F. A., Indianapolis, June, 1904).

"Shrinkage Troubles and Methods of Feeding." T. D. West (N. E. Foundrymen's Association, Boston, October 12, 1904).

"Fan and Positive Pressure Blower Tests." H. E. Field. **No. 291. Each A.**

Electric Furnace Methods in Iron and Steel Manufacture in Comparison with the Ordinary Metallurgical Processes. B. Neumann. "Electrochemical Industry," December, 1904. 1,500 w. — The author concludes as follows: "To sum up, we should expect that in the United States the blast furnace will continue to be used for reducing pig iron from ores, the open-hearth furnace and the Bessemer converter for making the ordinary steels, while only for making special steels and high per cent ferro-alloys the electric furnace can be used economically." **No. 292. B.**

Some of the Significant Features of American Rolling-Mill Practice. D. F. Nisbet. "The Iron Trade Review," October 27, 1904. 6,000 w., illustrated. — The author describes the principal features of American rolling mills, including steam

generation, condensers of mill engines, hydraulic systems, electrical appliances, ingot stripping, pit furnaces and various kinds of mills. **No. 293. A.**

The Cleveland Furnace Company's Plant. "The Iron Trade Review," December 22, 1904. 3,000 w., illustrated.— Description of a blast-furnace plant erected by Rogers, Brown & Co., at Cleveland, Ohio, and which has been in operation something more than a year. **No. 294. A.**

Automatic Pig-Iron Casting, Cooling and Conveying Plant. "The Iron and Coal Trades Review," November 25, 1904. 1,500 w., illustrated. — An illustrated description of a pig-iron casting and conveying plant erected at Middlesbrough. **No. 295. B.**

Steel v. Cast-Iron Water Mains. "Iron and Steel Trades Journal," December 10, 1904. 2,000 w. — Report of a committee appointed to investigate the relative merits of steel and cast-iron water mains in connection with the renewal of the Bombay water mains. **No. 296. B.**

The Hoisting Problem at Iron Mines. James R. Thompson. "The Iron Trade Review," December 1, 1904. 6,000 w., illustrated. — A paper read at the meeting of the Lake Superior Mining Institute, August, 1904. **No. 297. A.**

Profit in the Use of High-Speed Steel. W. B. "The Iron Age," December, 1904. 1,700 w. **No. 298. A.**

Heavy Duty Engines in Steel Plants. A. L. Strickland. "The Iron Trade Review," December 1, 1904. 1,500 w. **No. 299. A.**

Iron and Its Early Manufacture in England. A. R. Bell. "Machinery," December, 1904. 1,600 w., illustrated. **No. 300. B.**

METALLURGICAL NOTES AND COMMENTS

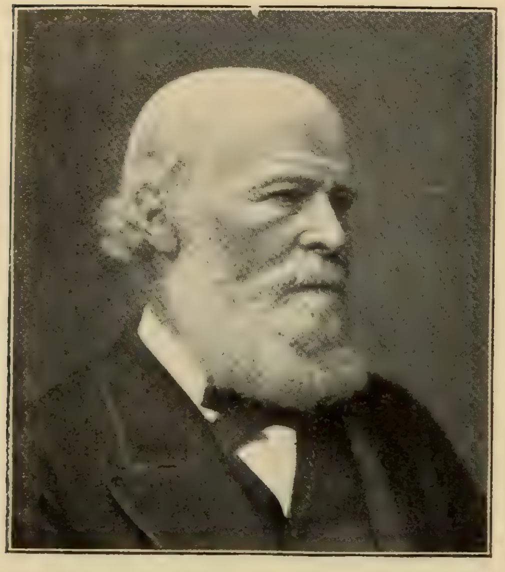
Benjamin Talbot. — Benjamin Talbot, whose portrait is reproduced as a frontispiece to our present issue, was born in 1864 in Shropshire, England. After obtaining experience as a learner at the Ebb Vale Steel Works, he became assistant to the Dephosphorising Company, which controlled the Thomas and Gilchrist patents in England relating to the basic process. In 1890 Mr. Talbot came to the United States to start and build up the manufacture of basic open-hearth steel in the South, and became superintendent of the Southern Iron Company's works at Chattanooga, Tenn. In 1892 he accepted the position of superintendent of the steel department of the A. & P. Roberts Company, Pencoyd, Pa. Mr. Talbot introduced the basic open-hearth process at these works, and in 1898 devised his well-known continuous open-hearth process (generally known as the Talbot process). This process was successfully installed at Pencoyd, Pa., and afterwards taken up by Jones and Laughlin, Pittsburg, Pa., where they are now operating the largest steel furnace in the world by this method and are erecting additional furnaces of equal size, the economy of the process having been demonstrated to their satisfaction.

In 1900 Mr. Talbot resigned his position as manager at Pencoyd in order to devote his time to the introduction of the continuous process in Europe and in the United States. He has also devised mechanical gas producers which have been received with favor and are giving very good results.

Mr. Talbot has presented to the Iron and Steel Institute some papers on the continuous process, in 1900 and in 1903.

Sir Lowthian Bell. — Sir Lowthian Bell, the eminent metallurgist, whose death occurred on December 20, 1904, was born in 1815, and with his brothers, Thomas and John, founded the famous firm of Bell Brothers, known as the Clarence Iron Works,

Middlesbrough, England. The following short synopsis of his career is taken from the "Iron Age" for December 29, 1904:



"In the death of Sir Lowthian Bell the iron industry has lost one of its greatest leaders, a man who during his long life was ever foremost as one of the most painstaking and keenest of the investigators of its technical problems. A man of large affairs during the whole of his career, he possessed the characteristics of a scientist and a student. During nearly the whole of his business life he was at the head of the Clarence Works, at Middlesbrough, one of the largest concerns in Great Britain producing pig iron. He was for a generation one of the active directors of one of England's leading systems — the North Eastern Railway. He served as a member of Parliament for a number of years, and was made a baronet in recognition of his services.

"To American ironmasters Sir Lowthian Bell was best known as one of the pioneers in the scientific investigation of the phenomenon of the blast-furnace, the fruits of many years of experiment, study and research having been first laid down in the monumental work, 'The Chemical Phenomena of Iron Smelting,' which was published in 1872, and has become one of the classics of the metallurgy of iron.

"Nearly all Sir Lowthian's contributions to the development of iron manufacture have been printed in the 'Transactions' of the Iron and Steel Institute. He was one of the founders of that famous technical society and occupied the chair as vice-president at the inaugural meeting in London on June 23, 1869, at which the first president, the Duke of Devonshire, delivered his address. It was Bell who presented the first paper, at the first technical session, at Middlesbrough, on September 22, 1869,

entitled 'The Development of Heat and Its Appropriation in Blast-Furnaces of Different Dimensions.'

"He was president of the Institute from 1873 to 1875, and in 1874 was the first to be awarded the Bessemer gold medal.

"In 1876 Isaac Lowthian Bell was one of the jurors of the Centennial Exhibition, and during his visit to this country read a historical paper on June 21 before the American Institute of Mining Engineers on 'The Hot Blast, with an Explanation of its Mode of Action in Iron Furnaces of Different Capacities.' He was one of the first men elected an honorary member of the Institute.

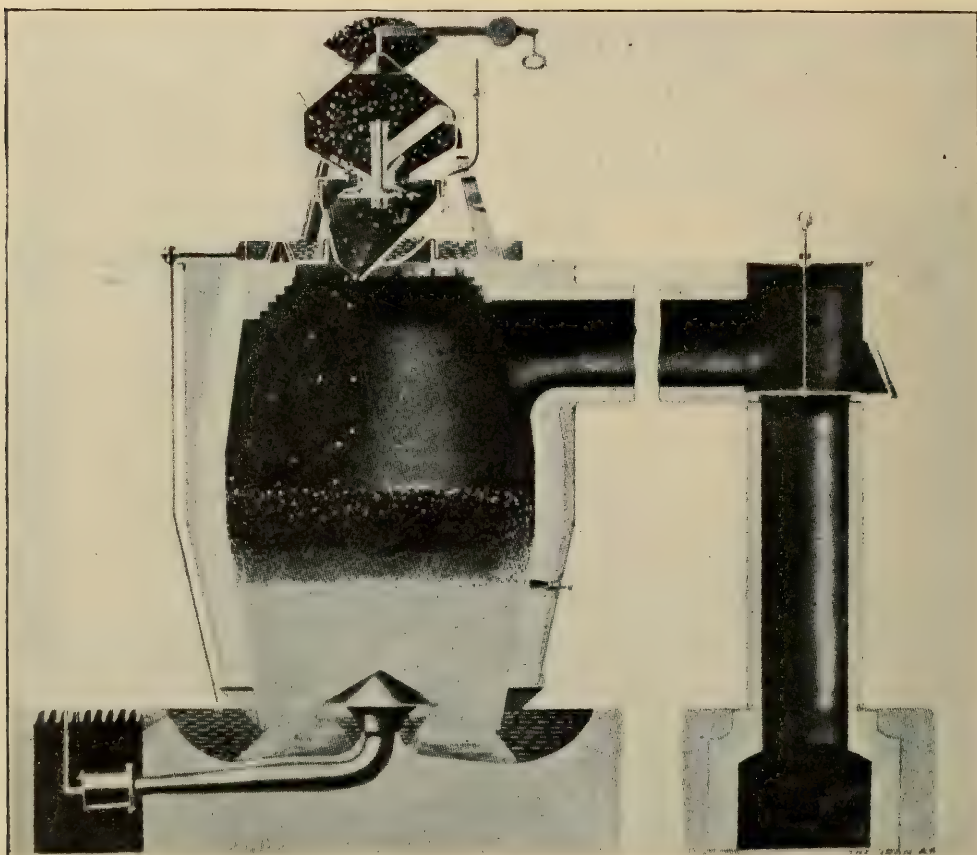
"The last visit which Sir Lowthian Bell made to this country was on the occasion of the first American meeting of the Iron and Steel Institute, and it was he who contributed a clear and thoughtful review of our industries to the special volume issued on that occasion. Through a number of visits, Sir Lowthian Bell kept in close and sympathetic touch with the development of the iron industry of this country, and it was only the sad affliction of his declining years — blindness — which prevented the Nestor of the iron industry from carrying out the cherished plan of taking part in the second visit of the Iron and Steel Institute this year.

"While during all his life he was most closely identified with the improvement of the iron smelting process, Sir Lowthian Bell keenly followed collateral branches of the subject. The fruit of prolonged labors in one line of important research was a paper read in 1878 on 'The Separating of Phosphorus from Pig Iron by the Use of Fused Oxides.' The researches made were the basis of a promising pig washing process, which, however, was soon lost sight of through the rapid development of the basic process which Thomas gave to the world soon after.

"Sir Lowthian Bell, with special facilities and interests through his connection as a director of the North Eastern Railway, was a very close observer of the wearing qualities of rails, and during the closing years of his life prepared an extraordinary monograph for private circulation on that subject."

A Model Gas Producer Plant. — The Lackawanna Steel Company has recently installed at its works at Buffalo, N. Y., one of the most complete gas producer plants ever built. The

plant is capable of gasifying 175 tons of bituminous coal per day, and consists of 16 Morgan continuous gas producers, provided with the George automatic coal feeder. The complete and efficient method of mechanically handling and distributing the coal to the producers and removing the ashes therefrom, which has been worked out by J. R. George, is believed to be a great improvement over any plan heretofore employed. The usual arrangement of fixed overhead coal bins



Sectional Elevation of the George Automatic Feeder on the Morgan Continuous Gas Producer

from which coal is drawn through spouts to each producer presents the following objectionable features:

1. Coal at any given part of the bins can only be used in the producer over which it rests.

2. The cost of construction of the bins distributed over a large battery of producers is high.

3. Considerable expensive machinery must be employed to distribute the coal over the entire battery of producers, and

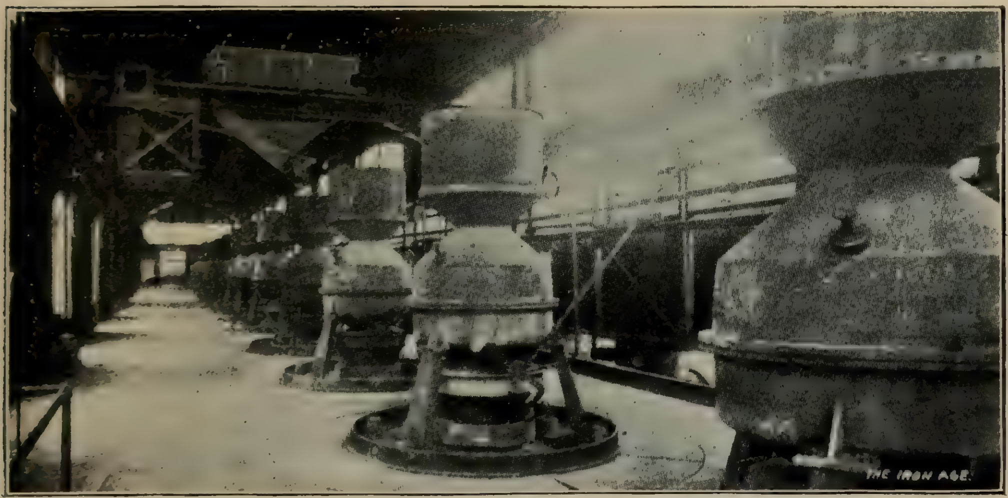
unless this machinery is in duplicate there is risk of the coal supply running short.

4. Daily records of coal used cannot be kept, nor can the amount charged to individual producers be ascertained.

All of these objectionable features have been avoided in the plant under consideration.

The accompanying illustrations represent quite fully the entire equipment, which may be described as follows:

The coal is received in hopper bottom dump cars alongside and near the center of the plant. Underneath the railroad track a large steel hopper is provided to receive the coal as it discharges from the cars and deliver it to the boot of a coal elevator. The



The Charging Floor, Showing the George Feeding Mechanism and Coal Charging Crane

coal is elevated by means of a simple bucket elevator running vertically only, and designed to discharge the coal into a central overhead bin having a capacity of 340 tons. The entire coal supply is carried in this one bin and is distributed to the producers as required by a light traveling car running under the central storage bin and over all the producers.

The distributing car or crane, designed by Mr. George, carries a fixed hopper of five tons capacity, resting on scales. A boy operator, sitting in the cage of the crane draws, fills the crane tank from the central storage bin, and discharges the coal as needed into the receiving hopper of producer in lots of 1,000 pounds or less. The crane tank carries 10,000 pounds. The

beam of the scale is conveniently located in front of the crane cage, and exact coal records are readily made for each producer.

The arrangement of large coal tank and distributing crane makes it possible to utilize the last pound of coal in any producer of a large battery and any additional gas units can be served without adding to the coal handling machinery, as one crane would be capable of serving about one hundred producers.

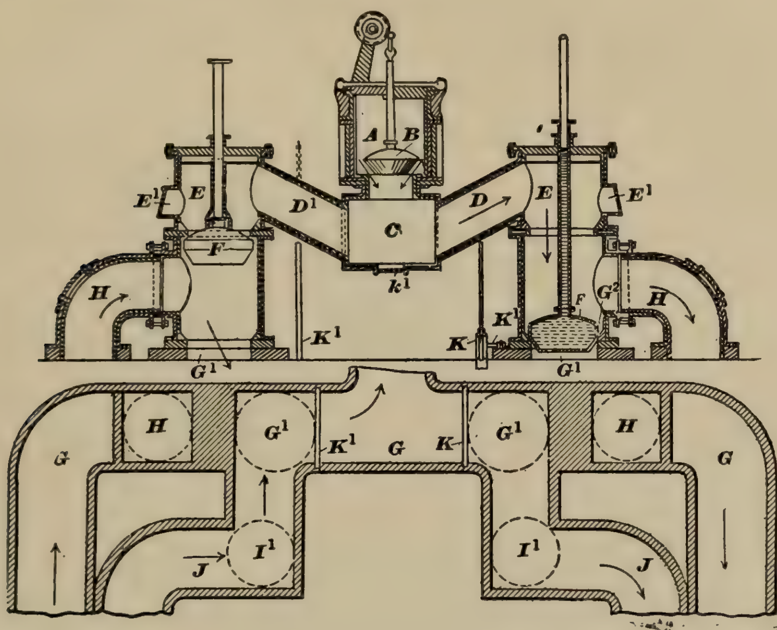
Over the same track on which the coal is received, and within a few feet of where the coal is dumped from the cars, a large ash reservoir is located, with a capacity of 2,000 cubic feet. The ashes, which are collected by hand from the bottom of the producer, are deposited in a skip bucket, in which they are elevated to the overhead bin. The ashes are taken away in the same cars in which the coal is brought to the plant, thus saving a switch for each car of ashes removed.

The entire equipment was built by Morgan Construction Company, Worcester, Mass., from its own designs. "The Iron Age," December 29, 1904.

New Valve Arrangement for Regenerative Steel Furnaces. — An invention which has been patented by Mr. H. W. Henderson, of 3 Dalmarnock Street, Glasgow, and which is about to be installed in a Scottish steel works, relates to the reversing arrangements in regenerative steel furnaces. The arrangement is illustrated in section and plan, Figs. 1 and 2, herewith. The gas is admitted into a chamber A which is fitted with two semicircular hinged lids provided with fireclay flanges. From thence the gas passes through a mushroom valve B into a chamber C provided with a hinged lower door C′ and a side soot-removing trap door, and traverses an inclined flue D or D′, as the case may be, into a vertical chamber E fitted with hinged soot-removing doors E′, which also act as safety valves for exit of any air. These vertical chambers are provided with duplex-shaped mushroom valves F which cover ports G′. Through these the gas passes by way of curved branches H into the main gas flue G.

The air is admitted through a port I′ provided with a mushroom lift-valve I, and passes along the usual flue J, as shown on the right-hand side of Fig. 2, to the gas and air regenerative chambers, from whence the gases pass into the furnace.

The waste gases from the furnace pass through the gas and air duplicate flues G and J, shown to the left of Fig. 2, and through the exit flue to the draught chimney, the air valve I being closed, and the gas valve F closed at top and open at bottom, as shown in Fig. 2. Damper plates or valves K, K′ are provided in the main flue so as to close at K the entrance to the chimney flue at the entrance of the gas, and open the same at K′ at the exit of the waste gases.



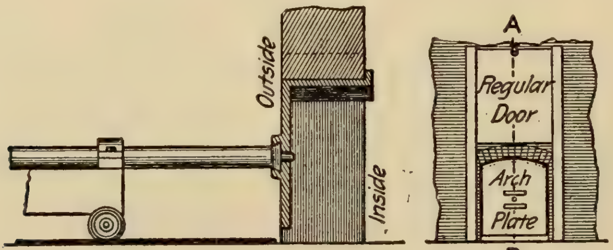
FIGS. 1 AND 2. Sectional Elevation and Plan of New Valve Arrangement for Regenerative Furnaces

The gas valves and dampers are controlled by chains passing over guide pulleys and attached to counterweights, and the air valves by chains attached to levers.

If desired, the valves F and K can be made hollow, as shown in the right-hand side of Fig. 1, so that water can circulate through them. Water can also be admitted to a passage in the upper seat of the valves F. The lower seat is built up of overlapping segments of firebrick. "The Iron and Coal Trades Review," November 25, 1904.

A Time-Saving Device for Steel Furnace Work. — The simple device shown in the illustration herewith merits attention as an example of the simplicity of means which may be

instrumental in producing large savings. The purpose of the device is to cut down certain losses of time which occur in steel furnace working, and its importance is therefore measured not by the value of the labor directly involved in its use, but by the value of labor and capital which wait on its work. To keep a steel furnace waiting for an hour while it might be turning out many tons of produce means a loss which has no relation to the direct cost of the work which causes the wait; conversely, if the time of wait can be largely reduced, the total gain is many times greater than the labor cost directly saved.



Section A-B. Front Elevation of Furnace.

The Johnson arch plate for furnaces is intended to facilitate the repair of charging-door openings. In the operation of mechanical charging, by means of a charging machine, the brick arch over the opening is often struck or grazed, and in consequence needs frequent repair. To make such repair possible, a temporary shield or bulkhead of brick has to be set up inside the opening as a protection to the workmen from the heat while renewing the arch. Setting up this bulkhead, by long-handled tools, is particularly slow and awkward work. The new device saves this work by providing a steel bulkhead, which may be quickly set and held in place by the charging machine. It also forms a center for the arch, so that the work of setting the arch brick is expedited.

Its construction is so simple as to require no explanation. A pair of lugs on the outside of the main plate is adapted to grip the nose of the ram of the charging machine. The upturned lip on the inside of the horizontal arch-shaped part of the plate forms a stop against which the arch brick are laid.

The door openings being generally of uniform size, a single

arch plate suffices for an ordinary plant. When a door arch is to be repaired, the plate is fixed on the ram, the regular sliding door is raised out of the way, and the arch plate is introduced and raised into place. After the brickwork is completed, the plate is lowered to clear the inside rib under the arch and is withdrawn, leaving the furnace ready to continue work.

This arch-plate has been patented broadly as a combined arch plate and shield by Mr. Frederick Johnson, of South Chicago, Ill. It is made by the Wellman-Seaver-Morgan Company, of Cleveland, Ohio. "Engineering News," December 29, 1904.

Magnetic Testing of Iron. — Iron which is to be used for electrical purposes must possess properties quite distinct from those which give it its value for ordinary mechanical uses, so that to determine its suitability for the former work some method of testing is necessary which shall give information bearing upon the end in view. The enormous amount of iron now being used in the construction of dynamo armatures, transformers, etc.; renders the question of the suitability or otherwise of certain brands of the greatest practical importance, in order that the efficiency of the apparatus may be as high as possible and its behavior agree with previous expectations. The two properties which are particularly desirable in transformer iron, or any iron subject to reversals of magnetism, are, firstly, a high permeability, or high magnetic induction in the iron due to a given magnetizing force, and, secondly, as small a loss by hysteresis as possible when the magnetism is reversed. The hysteresis loss in watts may be approximately calculated by an empirical formula due to Steinmetz, who found that, in general, it varied as the 1.6 power of the induction density, or it may be measured in the case of any given sample directly by a watt meter. But the permeability is usually determined by noting the change of induction due to the reversal of a known magnetizing force. The change of induction sets up a proportional instantaneous current in a coil of wire surrounding the specimen, the magnitude of which is indicated by the swing of a ballistic galvanometer in circuit with the coil. The galvanometer having previously been calibrated with a standard air coil, a numerical value for the change of induction can be

obtained, and the ratio this bears to the change of magnetizing force is a measure of the permeability of the iron.

In carrying out tests of this nature, it has been found that the results obtained were influenced to a great extent by the previous history of the iron, so that in order to arrive at some common basis of comparison, independent as far as possible of everything but the physical nature of the iron, Mr. G. F. C. Searle has made a number of investigations which were described by him in a paper read before the Institution of Electrical Engineers on December 8. The apparatus used in the experiments consisted of four solenoids arranged in the form of a square and containing strips of the laminations to be tested, the laminations overlapping at the corners of the square and being cramped together there to make the magnetic circuit as complete as possible. To make the induction as uniform as possible, the field at the ends of the solenoids was reinforced by additional coils, and other coils were arranged diagonally across the open corners. The ballistic galvanometer was connected to coils in the interior of the solenoids, and the whole arrangement was such that the iron strips could be inserted or withdrawn without interfering in any way with the electrical circuits. If ballistic tests were made of a sample of iron, it was found that at the first reversal of the magnetizing force a comparatively large swing occurred, the amplitude of which diminished at every succeeding reversal. From fifty to two hundred reversals were necessary before the iron arrived at a steady state, when the amplitude became appreciably constant. The final result, however, with small magnetizing forces, depended very much on the previous history of the iron, but it was found that this could be obliterated by reversing its magnetization many times, beginning with a comparatively high induction, and diminishing the latter gradually to zero. When any sample of iron had been demagnetized in this way, and then brought to a steady state by a repeatedly reversed constant force, the amplitude of the galvanometer swing corresponded to a point on a curve which the author called the "normal" permeability curve of the iron. The physical state to which the sample is reduced by demagnetization can be reproduced at will, and, therefore, serves as a convenient starting-point for experiments. If, after demagnetization, the iron be subjected to a compara-

tively great magnetic force, before commencing to obtain the permeability curve, the latter will be found to be considerably lower than the normal up to about the point corresponding to the greatest permeability, after which the two curves coincide. The discrepancy between them at low values may be very marked, for example, after the application of a magnetizing force of 8 units, the permeability corresponding to a force of 0.5 unit is less than a third of what it would have been if the previous magnetization had not taken place. Mr. Searle's paper is a long one, and the above results, as well as a great many others, are shown in the form of curves, which will be of interest to those concerned with the magnetic properties of iron. "Engineering," December 16, 1904.

Foreign Prices of Steel Rails. — The proposed organization of a European steel rail pool and its proposed price for export of £4 5*s*. per ton, virtually $21, calls attention to the possibility that steel rail exports to this country may be increased. The price above referred to might even be shaded if the pooling agreement should permit any of the countries in the pool to get rid of any part of its quota at a lower price. England has often sold rails several dollars per ton below $21, and as its iron and steel industries are just now depressed through foreign competition in its own markets, it might do so again and at an early day. It can even shade that price to-day, without waiting for the completion of the proposed pool. English quotations for steel rails on November 10 were as follows: At Middlesbrough, £4 11*s*. 3*d*.; at Barrow, £4; and at Cardiff, £4 7*s*. 6*d*. The lowest of these quotations, it will be seen, is below $20. Our own rail manufacturers are protected by a duty of $7.84 per ton and by ocean freight and other charges of about $2 per ton, and yet in the first nine months of this year we imported 34,231 tons of rails. In the same months last year we imported 87,273 tons.

A revision of the tariff that would reduce the steel rail duty, and thus compel a reduction in steel rail prices, would either close some of our rail mills or compel their owners to reduce the wages they are now paying to their workmen; they would also insist upon lower freight rates.

It is certain, too, that if the steel rail duty should be reduced, so would other iron and steel duties. Even the Western railroads would lose money by a reduction of iron and steel duties, because low duties mean low prices and low wages, and hence Eastern and Middle State interests which are so largely dependent upon the prosperity of our iron and steel industries would be compelled to buy more sparingly of the products of Western farms, and would thus give these Western roads less freight to carry from the agricultural states. "The Bulletin of the American Iron and Steel Association," December 10, 1904.

Early Suggestions of Dry Air Blast. — I have read with great interest the paper by Mr. James Gayley on the application of dry air blast to the manufacture of iron, which was so ably presented at the New York meeting of the Iron and Steel Institute last month. In glancing through the book "On the Manufacture of Iron," by Frederick Overman, M. E., published in Philadelphia in 1854, which I have in my library, I find the following, which is rather interesting as the opinion of an expert of half a century ago:

"The air introduced by the blast machine into the furnace should be as dry as possible. The main reason that blast furnaces do not work so well during the summer and clear warm weather as during winter and cold, rainy days in summer is that a large amount of watery vapors is mixed with the atmospheric air in hot weather. This water is very injurious in a furnace, as we shall hereafter see. To keep the air dry, the blast machine should be erected at the coldest and driest spot we can possibly select. We should take especial care that it is not exposed to the hot air around the furnace, and that it is beyond the reach of the steam engine, for the air will be more moist around the engine and the heated furnace than anywhere else. The best means of making a furnace work well during the summer would be to put the blast machine in an ice cellar."

A glance at the last sentence above shows us that the idea which is now so ably developed by a master mind was indeed a creation of a noted metallurgist of the old school. Richard Peters, Jr. — Letter to the "Iron Trade Review," December 1, 1904.

The Dry Blast. — In the absence of further data, it is difficult to account for the remarkable reduction in coke per ton of pig iron shown in Mr. Gayley's paper read before the Iron and Steel Institute. The elimination from the blast of 69 pounds of moisture per ton of pig iron would, according to the formulæ of Bell and Grüner, account for only 200 pounds of coke, yet the actual reduction was more than double this amount, notwithstanding the fact that, owing to the reduced volume of dry air, there was carried into the furnace by the blast a less number of heat units equivalent to 110 pounds of coke.

It is to be hoped that Mr. Gayley will make public the data necessary to make up the heat equation of the furnace while using dry air, so as to make a comparison such as was made by Sir Lowthian Bell in the discussion of Mr. Gayley's paper, "The Development of American Blast Furnaces, with Special Reference to Large Yields," published in the Transactions of the American Institute of Mining Engineers, Vol. XIX, page 959. N. M. Langdon. — Letter to "The Iron Age," December 1, 1904.

The Andrew Carnegie Research Scholarship. — The secretary of the Iron and Steel Institute has issued the following circular:

"A research scholarship or scholarships, of such value as may appear expedient to the Council of the Iron and Steel Institute, from time to time, founded by Mr. Andrew Carnegie (president), who has presented to the Iron and Steel Institute sixty-four one-thousand-dollar Pittsburg, Bessemer and Lake Erie Railroad Company 5 per cent debenture bonds, for the purpose, will be awarded annually, irrespective of sex or nationality, on the recommendation of the council of the Institute. Candidates, who must be under thirty-five years of age, must apply on a special form before the end of February to the secretary of the Institute.

"The object of this scheme of scholarships is not to facilitate ordinary collegiate studies, but to enable students who have passed through a college curriculum or have been trained in industrial establishments, to conduct researches in the metallurgy of iron and steel and allied subjects, with the view of aiding its advance or its application to industry. There is no

restriction as to the place of research which may be selected, whether university, technical school or works, provided it be properly equipped for the prosecution of metallurgical investigations.

"The appointment to a scholarship shall be for one year, but the council may at their discretion renew the scholarship for a further period instead of proceeding to a new election. The results of the research shall be communicated to the Iron and Steel Institute in the form of a paper to be submitted to the annual general meeting of members, and if the council consider the paper to be of sufficient merit, the Andrew Carnegie Gold Medal shall be awarded to its author. Should the paper in any year not be of sufficient merit, the medal will not be awarded in that year."

Iron and Steel Statistics. — The attention of our readers is called to the statistics printed in this issue on page 195 and referring to the world's pig-iron and steel output. They were prepared with great care and authority by the statistician attached to *The Iron and Steel Magazine* and we believe them to be the most up-to-date and accurate statistics yet presented. Leaving aside Mr. Swank's admirable statistical work, which is above criticism, the statistics printed from time to time in technical papers, even in those of the highest repute, are frequently inaccurate. One of these, generally considered as authority in such matters, recently published a table of the world's iron and steel production which was inaccurate in several respects; the figures showing the production of Russia were those of 1902, and not of 1903, although the latter had been published in that paper several months ago; notwithstanding the fact that the statistics for all the more important countries were available for the first six months of 1904, their estimates had in several instances been made without regard to them; again the general practice of mixing in gross and metric tons was followed; they estimated the production of Canada for 1904 at 300,000 tons against 265,418 tons in 1903, while Swank's statistics for the first half of 1904 showed a decrease of 15,000 tons, and 300,000 tons for the year can only be correct by the second half showing an increase of 50,000 tons, which is impossible. We merely mention these inac-

curacies as instance of the many errors which are allowed to creep into the statistics of otherwise responsible iron and steel publications.

We trust that our readers will appreciate the efforts we are making to furnish them with accurate statistical figures, and it is our hope that they will refer to our columns when in need of such information.

The Lake Superior Iron Ore Situation. — Informal conferences between merchant producers of Lake Superior ores at the beginning of the year resulted in the formation of a tentative schedule of prices as follows, compared with those which ruled quite steadily last season:

	1905	1904
Old range Bessemer	$3.75	$3.00
Old range non-Bessemer	3.20	2.60
Mesabi Bessemer	3.50	2.75
Mesabi non-Bessemer	3.00	2.35

These prices represent advances of 75 cents on Bessemers, 60 cents on old range non-Bessemer, and 65 cents on Mesabi non-Bessemer. They are all f.o.b. lower lake port, the seller paying the rail freight to upper lake port, and the vessel rate. The dock charge at the lower end of lakes is paid by the railroad out of the freight rate charged the consumer. The rail freight from all points in the Mesabi range through upper lake docks is 80 cents; from nearer points on the Vermilion range it is the same; from farther points on the Vermilion it is 90 cents, and from extreme points on the Vermilion it is $1.00. From the other three ranges the rates vary materially. Lake rates for the coming season are still a matter of conjecture; during the greater part of last season they were 65 cents from the head of the lakes (Duluth, Two Harbors and Superior, on Mesabi and Vermilion ore), 55 cents from Marquette, and 50 cents from Escanaba. With the same transport charges, Mesabi ores would net the producer, f.o.b. mine, $2.05 for Bessemer and $1.55 for non-Bessemer.

The standards of analysis on which the above prices are based are unchanged from previous years. On Bessemer ores the standard is an ore containing 63 per cent iron, when dried at 212°, and 10 per cent moisture, natural, making the iron

content in the natural state 56.7 per cent. The standard phosphorus content is .045 per cent, dried. The invoice price of a given ore is determined in proportion to the number of units of iron relative to the standard, some ores earning premiums and others being subject to penalties. The ore being sold at lower lake port, the furnace man does not lose the freight paid on impurities to this point; beyond it he does, as well as the extra cost of smelting, due to impurities. The value of the ore, dependent on its phosphorus content, is determined by the standard phosphorus table. This table is constructed according to a simple rule: The phosphorus differential is, of course, zero for .045 per cent phosphorus; each .001 in phosphorus above or below carries a new value, the rate of progression being the same after the first point, so that the following excerpt from the middle of the table illustrates the whole:

P. %	Rate of Progression $	Phos. Value $
.048	.0090	—.0255
.047	.0085	—.0165
.046	.0080	—.0080
.045	.0000	.0000
.044	.0080	+ .0080
.043	.0085	+.0165
.042	.0090	+ .0255

On non-Bessemer ores the standard is an ore containing 60 per cent iron, dried at 212°, and 12 per cent moisture, natural, making the iron content, natural, 52.8 per cent.

For several years past the average iron content of all ores brought down has decreased, owing partly to the gradual exhaustion of the purer ore bodies, which naturally were the first exploited, partly to producers casting aside smaller proportions of the leaner ores necessarily arising in the operations of mining, and partly to the exploitation, on account of increasing demand, of ore bodies which formerly were not regarded as of sufficient value to develop.

From the current market prices of iron ore it is not possible to compute with great accuracy the cost of producing pig iron. In the first place, the bulk of the ore brought down goes to consumers who have mined it themselves, while another large part goes to consumers who have it on long-term contracts.

To both these classes the cost is less than the open market price. Very few, if any, consumers buy as much as half their ores for a season at a time, the ore bought in the open market being in general merely to round out mixes. In the second place, the ores available in the open market are in general below the standard analysis, and in dealing with these ores the coke and limestone consumption would have to be assumed at considerably more than the quantities known to prevail in the practice of the best producers.

A number of estimates have been made as to the movement the coming season. Some estimates have been as high as 30,000,000 tons, of which the United States Steel Corporation would move 18,000,000 tons; other estimates have been at 28,000,000 tons, while the lowest is 25,000,000 tons. The writer is disposed to conclude that the higher estimates are more likely to prove correct. The movement in recent years has been as follows, from the whole Lake Superior region on the American side:

Year	Gross tons
1900	19,059,393
1901	20,593,537
1902	27,571,121
1903	24,281,595
1904	21,800,000*

The production of pig iron in 1902 and 1903 was approximately 18,000,000 tons; the production in 1904 was approximately 16,560,000 tons. There was an accumulation of ore as a result of the heavy movement in 1902, but estimates are that the current rate of production will exhaust all ores by July 1, or not long after the coming season opens. The country is now producing pig iron at the rate of 21,000,000 tons per annum, and substantially all the increase, as compared with 1902 or 1903, comes from districts tributary to Lake Superior ores. If this rate of production is continued into 1906, it is submitted that a Lake Superior ore movement of close to 30,000,000 tons will not prove excessive. Written for *The Iron and Steel Magazine.*

* Approximate.

REVIEW OF THE IRON AND STEEL MARKET

January, almost invariably a dull month in the iron trade, has had particular cause to be dull on this occasion. The sharp buying movement which in October put a sudden end to the slackness which prevailed almost continuously in 1904, up to that time, was continued until shortly before the holidays, and gave furnaces and mills an unusually large tonnage of business with which to begin the new year, at the same time removing the necessity for buyers to resume their purchases early in the new year. It is therefore no untoward sign in itself that January has been a dull month. Prices of pig iron have receded from 25 to 50 cents a ton, while finished products have been firmly maintained. The slight reaction in pig iron is hardly more than natural in view of the advance, almost unparalleled, considering the circumstances, which occurred in the closing months of last year. Of course, the dullness has given rise to expectations in some quarters that 1905 will not justify all the happy auguries that have been entertained for it, but giving all such considerations full weight, it can be said with great confidence that the year upon which the American iron trade has entered will break all records for production, while prices, even if not in all cases maintained at those now ruling, will still be quite remunerative.

It is true that since the great pressure upon producers in 1902 there have been large additions to capacity, but in previous cases it has required but a few brief years for the natural increase in consumptive demand to overtake even greater increases in productive capacity. Demand grows rapidly in the United States, and it is the rule rather than the exception for each year to break the best record of previous years in production.

Pig Iron. — The month of January opened with pig iron being produced at the rate of 20,000,000 tons annually. During the month a number of blast-furnaces have resumed operations, and these, with a few definitely scheduled to resume about the

first of February, will easily bring the current rate of production to 21,000,000 tons annually in the early part of February. While approximately this rate has been attained occasionally in the past, it has never yet been sustained, the greatest production in a calendar year having been 18,009,252 tons, in 1903, and the greatest production in any consecutive twelve months having been about 19,050,000 tons, in the twelve months ending with September, 1903. The iron being produced is going into consumption, as unsold stocks in the hands of merchant furnaces were reduced during December, and no particular accumulation is believed to be occurring at present. The steel works certainly have no surpluses, all being close to the danger line. On January 11 a sale of 25,000 tons of Bessemer pig was made by W. P. Snyder & Co. to the United States Steel Corporation at $15.50, valley furnace, for January delivery. At the same time some 6,500 tons out of 15,000 tons passing between the same interests for December shipment was canceled, the iron not having been delivered in the month. It is reported that the seller purchased about 12,000 tons of "speculative iron" to apply on the sale. Some other speculative lots have also been disposed of, and this is regarded as clearing the situation, notwithstanding that the openly quoted market had been $15.75 to $16, valley, prior to such sales. A lot of 7,000 tons of Bessemer iron passed from the Ohio Iron and Metal Company (a scrap concern) to the Lackawanna Steel Company, in exchange for scrap. This company also took some other lots of Bessemer. A Pittsburg consumer bought, about the middle of the month, 5,000 tons of forge, at $16.10 to $16.25, delivered. A number of sales of foundry iron have been made, generally at $16 at central western furnace, it being reported, however, that this price was shaded in some instances. We quote the market as follows: F.o.b. valley furnace: Forge, $15.25 to $15.50; No. 2 foundry, $16 to $16.25; Bessemer and basic, $15.50 to $16. At Pittsburg: Forge, $16.10 to $16.35; No. 2 foundry, $16.85 to $17.10; Bessemer and basic, $16.35 to $16.85. At Birmingham: Forge, $12.75; No. 2 foundry, $13.75. At Philadelphia: Standard gray forge, $15.75 to $16; No. 2 foundry, $17.25 to $17.75; basic, $15.75 to $16.25. At Chicago: Northern No. 2 foundry, $17 to $17.50; malleable Bessemer, $17 to $17.50.

Steel. — The crude steel market is even stronger than it was at the close of December, since premiums of from \$2 to \$2.50 are the rule, referred to the official prices of \$21 on billets and \$23 on sheet bars, f.o.b. Pittsburg. It is very difficult to buy steel for any distance ahead, while prompt lots are naturally difficult to secure, as the producers are so busy in their own finishing mills. Open-hearth steel is scarcer than Bessemer, although nominally the same price.

Shapes. — While this is the dull season in structural lines, some good contracts have been placed, and the outlook is not unfavorable. Prices remain: Beams and channels, 15-inch and under, zees and angles, 2 x 3 to 6 x 6 inclusive, 1.50 cents; tees, 1.55 cents; beams and channels over 15-inch, 1.60 cents.

Plates. — The market has been decidedly quiet. Mills are still running on old specifications received from steel car builders, but in all directions new business is rather light. Prices remain: 6¼ to 14 inches wide, inclusive, 1.40 cents; over 14 inches and not over 100 inches wide, 1.50 cents, for tank quality, quarter-inch and heavier; with extras for quality, for lighter than quarter-inch, and widths beyond 100 inches.

Merchant Bars. — Little new business has come out in steel bars, but tonnage has been fairly good in iron bars. We quote Bessemer and open-hearth steel bars at 1.40 cents, half extras, f.o.b. Pittsburg, and common iron bars at 1.65 cents, f.o.b. Youngstown.

Sheets. — Business has been quiet, as the mills, particularly those of the leading interest, were already well booked. Prices are firm at 2.30 cents for black and 3.35 cents for galvanized, No. 28 gauge, f.o.b. Pittsburg. Tin plates are quiet. While January usually sees the inauguration of an active demand, this time the business was done earlier. The market remains at \$3.55 for 100-pound cokes, f.o.b. Pittsburg.

Merchant Pipe. — On January 2 discounts were reduced one-half point, effecting an advance of about \$1.00 per net ton on all iron and steel merchant pipe.

Scrap. — The market has been quiet, the deadlock already referred to between dealers and consumers being continued, with no signs of weakening on either side. Heavy melting stock is quoted at \$16.50 to \$17.

STATISTICS

The World's Pig Iron Output.* — Estimates with a probable error of a very few hundred thousand tons can now be made of the world's production of pig iron in 1904, while later returns permit a revision of our figures for the 1903 production, presented last May, reducing the total by 267,119 gross tons. Definite statistics for 1903 have now been presented for all countries, except that the latest for Austria-Hungary are those for 1902, and that various minor countries, such as Mexico, have never presented statistics, the total of such sporadic production being estimated at a little over 200,000 tons.

The 1904 estimates are based, in the case of the United States, Germany, Great Britain, France, Russia, Belgium and Canada, on returns for the first six or nine months of the year, the estimate for the United States being further reinforced by a study of monthly returns, and all other estimates being based upon a careful consideration of current conditions. Attention is called to the fact that all returns made by the original authorities in metric tons have been reduced to gross tons, a practice not generally followed in other compilations of the world's production, and introducing an obvious error of 1.6 per cent in figures totalling nearly 20,000,000 tons.

World's Pig-Iron Production; Tons of 2,240 Pounds

	1903	1904	Change
United States	18,009,252	16,497,033	—1,512,219
Germany	9,926,251	10,000,000	+73,749
Great Britain	8,811,204	8,400,000	—411,204
France	2,782,986	2,900,000	+117,014
Russia	2,351,250	2,850,000	+498,750
Austria-Hungary	1,446,800†	1,575,000	+128,200
Belgium	1,278,679	1,285,000	+6,321
Sweden	498,825	500,000	+1,175

* Specially prepared by the statistician of *The Iron and Steel Magazine.*

† 1902.

	1903	1904	Change
Spain	374,274	350,000	—24,274
Canada	265,418	250,000	—15,418
Italy	74,092	75,000	+908
Other countries	205,969	217,967	+11,998
Total	46,025,000	44,900,000	—1,125,000

The decrease of more than a million tons in production from 1903 to 1904 only marks a slight halt in the grand march of pig-iron production. Had the United States maintained its rate in 1904, the world would have shown an increase of nearly half a million tons. The United States can be depended upon to interfere very seldom with the march. Usually it is the leader. It is now making pig iron at the rate of 21,000,000 tons per year, or 3,000,000 tons more than its record production for a calendar year. Statistics of the world's pig-iron production for previous years, prepared with the same care as the above, are not in general available, but in the table below are presented totals derived from a variety of sources, which are sufficiently accurate for comparative purposes. Beside them are set the figures for the three great iron countries, from which the rapid gain of the United States is easily observed.

Pig-Iron Production, Tons of 2,240 Pounds, except Germany, Tons of 2,204.6 Pounds.

	World	United States	Great Britain	Germany
1800	825,000		175,000*	
1830	1,825,000	165,000*	677,417	
1850	4,575,000	563,755	2,300,000*	205,342†
1860	7,400,000	821,223	3,826,752	
1870	11,900,000	1,665,179	5,963,515	1,409,429
1880	17,950,000	3,835,191	7,749,233	2,729,038
1890	27,157,000	9,202,703	7,904,214	4,658,450
1900	40,100,000	13,789,242	8,959,691	8,520,541
1901	40,100,000	15,878,354	7,928,647	7,860,893
1902	43,575,000	17,821,307	8,517,693	8,402,660
1903	46,025,000	18,009,252	8,811,204	10,085,634
1904	44,900,000	16,497,033	8,400,000*	10,160,000*

Of course it is only in the last quarter century or so that the production of pig iron has constituted a true index to the

* Estimated.

† Statement of Herr Pechar for 1848.

magnitude of the iron industry proper; in earlier years much iron was produced which did not pass through the intermediate stage of pig iron.

Iron and Steel in Russia. — Official figures recently published show that the production of pig iron in Russia in 1903 was 2,453,953 tons, a decrease of 106,191 tons from the previous year. The output by districts was as follows: North Russia, 22,462 tons; Moscow, 95,594; South Russia, 1,366,437; Poland, 308,914; Ural, 660,546 tons. In Poland there was an increase of 26,612 tons over 1902; all the other districts showed decreases, the most important being in the Ural, where it was 69,797 tons.

The production of iron castings, or foundry work, was 209,000 tons, an increase of 19,000 tons. The wrought, or puddled, iron reported in finished forms was 194,000 tons, a decrease of 83,000 tons.

In steel production, however, there was an increase of 315,000 tons, or 15 per cent. The output of steel ingots and of finished steel is reported as follows:

	Ingots	Rolled Products	Castings
Bessemer	568,352	454,990	2,558
Open-hearth	1,764,109	1,499,952	31,901
Crucible	1,705	1,943	......
Totals	2,334,166	1,956,885	34,459

The proportion of steel made by the various methods was: Bessemer, or converter, 24.3; open-hearth, 75.6; crucible, 0.1 per cent.

The approximate consumption of iron is given as follows, finished material and machinery being reduced to terms of equivalent pig iron:

	1902	1903	Changes
Pig iron produced	2,560,000	2,454,000	—106,000
Imported as pig	18,000	13,000	— 5,000
Imported in finished forms	327,000	336,000	+ 9,000
Total consumption	2,905,000	2,803,000	—102,000

The consumption of iron per head in Russia is much less than that of any other European country. Exports are not

given in the table, as there is practically no iron or steel exported from the country. "Engineering and Mining Journal," December 1, 1904.

Iron and Steel Works of Canada. — The following information relating to the iron and steel works in Canada was published in the Bulletin of the American Iron and Steel Association for December 25, 1904:

Number of blast furnaces in Canada, 16 completed and 3 projected. Of the completed furnaces, 11 use coke and 5 use charcoal for fuel. The projected furnaces will use coke. Annual capacity of the completed furnaces, 755,000 gross tons of coke pig iron and 75,000 tons of charcoal pig iron; total, 830,000 tons.

Number of rolling-mills and steel works in Canada: 18 completed, 3 building and 2 projected. Of these, 1 makes Bessemer steel, 1 has an idle modified Bessemer converter, 1 makes Tropenas steel, 5 make open-hearth steel, and 1 open-hearth steel plant and 1 plant for the manufacture of steel by the Hunter process are being built. Annual capacity of built and building plants on double turn: Standard Bessemer and Tropenas ingots and castings, not including the idle modified Bessemer converter, 200,800 gross tons; open-hearth ingots and castings, 451,000 tons; Hunter steel castings, 1,500 tons; total ingots and castings, 653,300 tons; total finished rolled and forged products, 839,600 tons.

CORRESPONDENCE

Alternate Stresses

To the Editor :

An alternate stress testing machine was rigged in our laboratory as early as 1893 along the lines of the one used at the Watertown Arsenal.

In that machine series of tests were conducted with all kinds of steel specimens, from the lowest to high carbons, nickel alloys, both tubular and solid sections. Specimens were tested, treated and untreated, annealed and cold drawn, so that, altogether, the writer has in his mind a general impression of results obtained that have naturally a pretty strong backing in the way of a large number of results from this kind of test.

The loads applied were always in relation to the elastic limit of the material, and not only was this calculated, but the deflection also was noted. Of course, these two go together, and the deflection measured bore a very close relation to that given by calculation. One broad fact is very distinctly impressed upon the mind of the writer as the result of these tests, and that is that the larger the grain of the material tested, because of its condition or kind, the less punishment will it stand under alternate stress.

A second impression is that any sudden change of diameter at or near the point of maximum stress produces failure quickly and out of all proportion to the stresses involved. It behaves just as a nick does in a bar of steel when broken on the anvil,— it makes a breaking point. A third strong impression is that if the stresses produced by a bending moment can be made to distribute themselves over even a short distance of the length of the bar under stress, the endurance of the piece will be much greater than if the stresses are centered over a section amounting to only one plane, to all practical purposes. A bar with a uniform bending moment will endure forever. This impression, of course, bears a close relation to the previous one, —

a nick or sudden reduction of diameter does center all stresses at one place.

These impressions lead the writer to one line of thought as to what goes on in a metal under alternate stress. It appears certain that if the stresses are concentrated at one point or plane, rupture will take place sooner or later, even at a very small maximum fiber stress.

The particles of metal making up a bar such as is tested or used in the construction of machinery have a certain definite attraction for each other. What holds these particles together may be described in all manner of scientific language, but there is a certain definite attraction. There are individual particles making up the mass, just as individual particles make up a mass of granite. There are, therefore, natural lines of separation between these particles. It seems most probable that when the strains are centered at one point, slowly and surely these particles are obliged to relinquish their hold upon each other. Constant, minute, infinitesimal rubbing of one particle upon another creates a continuous line of minutely small fractures. These spread and progress without any external evidence until finally rupture takes place under, possibly, the lightest load the part is ever called upon to bear. There is no crystallization, of course, no change of shape, and the particles involved simply gradually separate.

The fact that heating will restore such steel to nearly its original condition would indicate that the particles regain such relation to each other as they had before testing. How this can occur is beyond my comprehension, but it surely does occur, and a specimen reheated after alternate stress will live longer under such stress than one which is tested to a finish without interruption.

In a recent article in *The Iron and Steel Magazine* it has been stated that the peculiar fracture shows that the crack begins at the outside or at some point and progresses. The appearance of the fracture is pointed out as indicating this.

This I cannot agree with, because the most careful microscopical examination will not show any such crack or beginning of a crack up to an exceedingly short interval before complete rupture.

The peculiar fracture the writer believes to be what may

be called the accident of breaking; that is, the manner in which it broke. For example, a high carbon, tempered specimen always breaks with a dividing line squarely through the greatest diameter, one half of the fracture being satin-like and glassy in its nature; the other side granular. This I believe to be because at the instant of rupture with the full load upon it, one half was broken in tension and the other half in compression. I believe that the minute fractures were evenly distributed throughout the mass, just as far as the homogeneity of the material and its make-up would allow.

In cases where there is a key-way or pin hole, or some other artificial breaking point, then I do believe that the minute fractures begin at that point and gradually spread until the time of rupture comes.

It has been shown without question that high carbon steels, nickel steels, and heat-treated steels of all kinds will stand alternate stresses better than low carbon and other open-grained or large-sized crystals. This means that a fine-grained steel is better every time than a coarse-grained one. This means, in the mind of the writer, that the minute fractures which begin in all steel have a harder and slower time in progressing and are obliged to progress by smaller steps than is the case with the steel of large grain. With such steel, or with cast iron as an exaggerated form, each fracture when its get started at all can, and probably does, cover the whole side of a grain or crystal at once, and it takes comparatively few minute ruptures to extend over a considerable area and to bring about final rupture.

All this may not be very scientific, but it is not intended that it should be. It does indicate, however, that for alternate stress fine grain must be sought after to give long life. Such fine grain may be obtained in various ways, — by chemical composition, by heat treatment, by cold work, and by properly conducted hot work which is in the nature of heat treatment.

HENRY SOUTHER.

HARTFORD, CONN., December 9, 1904.

Steel Ties

To the Editor:

Sir, — The item on pages 77, 78 of the January, 1905, issue of *The Iron and Steel Magazine* furnishes an instance of how

easy it is for a glaring error to elude several successive scrutinies. This item, referring to the Carnegie steel railroad tie, you credit to the "Iron and Steel Trades Journal," but this publication in turn had taken it from "The Iron Age" of November 3, page 28 (without credit, by the way), and I suspect "The Iron Age" rewrote it from some daily paper. At any rate, the item on each successive appearance has contained the words, "These steel ties weigh 19¾ pounds each," which is absurd. All the ties I have heard of weighed from 150 to 175 pounds each, and I know of an effort to make a 125-pound tie which was abandoned. As a matter of fact, the Carnegie tie weighs 19¾ pounds *per foot*, making the total weight between 150 and 160 pounds. If the tie weighed only 19¾ pounds apiece, the cost would be below that of the wooden tie, and there would be no question about its immediate adoption, assuming the design to be satisfactory. In an editorial in "The Iron Trade Review" of October 8, 1903, it was shown that, disregarding the cost of the actual work of replacement as being too uncertain to be figured, that, from interest and sinking fund considerations, a steel tie could have a cost double that of a wooden tie if it lasted twenty-five years, but that if it lasted forever, the cost could not be much more than double, as the interest charge would exceed the sinking fund needed to replace the wooden tie every eight years. Accordingly, a tie weighing 175 pounds each would be prohibitive, unless for experimental purposes.

I mention this matter as I have taken a special interest in the steel tie for a long time, being satisfied that its day will come, and when it does, steel ties will furnish a larger tonnage to the iron industry than steel rails.

Besides the orders from the Lake Shore and New York Central roads (which were 3,000 ties each, and not 7,000 and 5,000 respectively, as stated in the item), I understand the Duluth and Iron Range has taken 2,000 and the Bessemer road 1,200, these interests being identified with the Carnegie Steel Company through the United States Steel Corporation, while the Pennsylvania Company has taken 500.

STEEL TIE.

PITTSBURG, January 14, 1905.

RECENT PUBLICATIONS

The Electric Furnace, by Henri Moissan. Translated from the French by A. T. de Mouilpied. 303 $4\frac{1}{2} \times 8\frac{1}{2}$ in. pages; 42 illustrations. Edward Arnold. London, 1904. Price, $2.75. — A few months ago the Chemical Publishing Company, of Easton, Pa., published a translation of this valuable book by Victor Lenher of the University of Wisconsin, and we refer our readers to *The Iron and Steel Magazine* for September, 1903, for our review of this book. That a second English translation should have been made is evidence of the great interest of many scientists and engineers in Professor Moissan's work. The present edition embodies the original French edition, together with the new matter incorporated in the German edition. Professor Moissan, moreover, has written, specially for this edition, a chapter dealing with the most recent work.

This book is divided into five chapters. In the first are described the different types of electric furnaces used in these researches, and their application to the study of the fusion and the volatilization of a number of refractory bodies. The second chapter contains a study of the three varieties of carbon: amorphous carbon, graphite and the diamond. Chapter III deals with the preparation of some elements in the electric furnace. The elements investigated were chromium, manganese, molybdenum, tungsten, uranium, vanadium, zirconium, titanium, silicon and aluminum. Chapter IV contains an account of the researches carried out on some new series of binary compounds — the carbides, the silicides and the borides. The preparation, properties and analyses of hitherto unknown compounds are given. More especially the preparation of calcium carbide has been subjected to fresh investigation, and this is dealt with in some detail. Finally come a number of general conclusions.

The Art of Pattern Making, by I. McKim Chase. 254 $4 \times 7\frac{1}{2}$-in. pages; 215 illustrations. John Wiley & Sons. New

York, 1904. Price, $2.50. — As the author rightly says in his preface, the literature pertaining to pattern making is by no means as extensive as the importance of the business warrants. The subjects chosen for illustration "are chiefly those with which the author has had personal experience and were originally written for publication in 'Machinery.' He also records the experience of others in pattern making; these examples have been selected chiefly from the correspondence of the 'American Machinist.' He also embodies whatever in his opinion would be of interest to the pattern-making fraternity." The book includes numerous examples of all kinds of pattern work for green sand, dry sand and loam molding, and contains much useful information and many rules for practical use of pattern-makers and others. The book is printed and bound in the usual attractive and serviceable form which characterizes the technical publications of John Wiley & Sons.

Radio-Activity, by E. Rutherford, professor of physics, McGill University, Montreal. 399 $4\frac{1}{2} \times 8\frac{1}{2}$-in. pages; 60 illustrations. Cambridge University Press. Cambridge. 1904. — In this work the author has endeavored to give a complete and connected account, from a physical standpoint, of the properties possessed by the naturally radio-active bodies. The author states that he has found the theory that the atoms of the radio-active bodies are undergoing spontaneous disintegration extremely serviceable, not only in correlating the known phenomena, but also in suggesting new lines of research. A brief account is given in the book of the electric properties of gases to the extent that is necessary for the interpretation of the results of measurements in radio-activity by the electric method. The book is well printed and attractively bound. The number of the chapter is indicated at the top of each page opposite the page number, a feature which is much to be commended.

Experiments for Students in General Chemistry, by Edgar F. Smith, professor of chemistry, University of Pennsylvania, and Harry F. Keller, professor of chemistry, Central High School of Philadelphia. Fifth edition enlarged. 92 $4\frac{1}{2} \times 7$-in. pages; 40 illustrations. P. Blakiston's Son & Co. Philadelphia. 1905. — This little work is designed as a guide for beginners in chemistry. Its object is not to dispense with the supervision

of an instructor, but rather to assist him. In the present edition new experiments have been introduced, while others, described in other editions, have been modified.

Elaboration des Métaux Dérives du Fer (Extraction of the Metals Derived from Iron), by L. Gages. First part: Metallurgical Furnaces. 160 $4\frac{1}{2} \times 7\frac{1}{2}$-in. pages; illustrated. Paper covers. Second part: Metallurgical Reactions. 175 $4\frac{1}{2} \times 7\frac{1}{2}$-in. pages; illustrated. Paper covers. Gauthier Villars. Paris. Price, $0.75 each. — These two little volumes belong to the well-known series of "Encyclopédie Scientifique des Aide-Mémoire," published by Gauthier Villars, and in which are included many valuable short treatises on numerous subjects dealing with applied science. The author's description of iron metallurgical furnaces and of the reactions taking place in the production of iron and steel, while necessarily brief, are very clear and systematically grouped. The student and even the expert cannot fail to find much that is instructive and helpful in these two excellent little books.

Travail des Métaux Dérives du Fer (Working of the Metals Derived from Iron), by L. Gages. 198 $4\frac{1}{2} \times 7\frac{1}{2}$-in. pages; illustrated. Paper covers. Gauthier Villars. Paris. Price, $0.75. — In this little volume which, like the preceding ones, belongs to the "Encyclopédie Scientifique des Aide-Mémoire" series, the author deals with the treatment of iron and steel, both mechanical and thermal, as well as with the constitution of these metals as revealed by metallographic methods. The subject is clearly and very satisfactorily presented, and this little book should be read by metallurgists and engineers possessing the necessary knowledge of French.

Essais des Métaux (Testing of Metals), by L. Gages. Part I: Testing Machines. 150 $4\frac{1}{2} \times 7$-in. pages; illustrated. Part II: Theory and Practice. 168 $4\frac{1}{2} \times 7$-in. pages; illustrated. Paper covers. Gauthier Villars, Paris. Price, $0.75 each. — In these two little books, which belong to the "Encyclopédie Scientifique des Aide-Mémoire" series, the author presents a concise but lucid description of the physical testing of metals and of the testing machines required.

Grundzüge der Siderologie, by Hanns Freihen V. Jüptner. Volume III, second part. 275 $6 \times 8\frac{1}{2}$-in. pages. Arthur Felix.

Leipzig. 1904. Price, $3.25. — This is the last installment of Professor von Jüptner's important work in Siderologie, or the science of iron, and is devoted to the metallurgical processes by which iron and steel are obtained. It will be remembered that the first volume of this series was translated into English by Charles Salter, and we must hope that the last two volumes will soon be likewise translated.

Konstruktionsstahl (Construction Steel), by Otto Thallner. 298 6 × 8¾-in. pages; illustrated. Paper covers. Von Craz and Gerlach. Freiberg. 1904. Price, $3.25. — The author describes the properties, constitution and treatment of iron and steel in the light of modern research. This book should be read by all those interested in the constitution of steel and in its rational treatment.

Die Roheisen, published by the Ministry of Commerce. Two volumes. 760 7½ × 10-in. pages. Paper covers. Vienna. 1904. — These volumes contain exhaustive statistics relating to the production of iron ore, coal, pig iron and iron wares, compiled from reports of government officials. They include the consumption, imports and exports of all countries. Some of the statistics are brought down to 1902.

Annual Report of the Smithsonian Institution, for the year ending June 30, 1903. 876 6 × 9-in. pages. Profusely illustrated. Government Printing Office. Washington. 1904. — Besides the secretary's report, this excellent annual publication contains the usual number of reproductions of important articles, covering a wide field of scientific research.

The Chemical Engineer, Vol. I, No. 1. November, 1904. 68 6 × 9-in. pages; illustrated. The Chemical Engineer Publishing Company. Allentown, Pa. Subscription, $3 per year; single copies, 25 cents. — This is the title of a new monthly periodical devoted to practical, applied and analytical chemistry. It is edited by Richard K. Meade. This first number contains an unsigned article on the valuation of coal for steaming purposes, an article on the rapid volumetric determinations of lime in limestone, cement, blast-furnace slag, etc., by R. K. Meade, a short article from Robert Job on protection of structural work from rust, and some reprints from articles published in other journals.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

775,350. FEED MECHANISM FOR ROLLER-MILLS. — John J. Gerard, Minneapolis, Minn., assignor to Allis-Chalmers Company, Chicago, Ill. In feeding mechanism for roller-mills, in combination with the feed-gate, a vertical adjustment and suspension therefor, consisting of plates provided with perforations, rounded blocks resting on the edges of the perforations, and adjusting screws passing through the blocks and supported thereby.

775,563. REVERSING-VALVE FOR FURNACES. — Samuel M. Guss, Reading, Pa. A reversing-valve for regenerative furnaces comprising a valve-box having four ported walls and a central bar, and four slide-plates arranged between said central bar and the corners of the box and adapted to be moved into and out of the box to control communication between the ports.

775,641. GAS-GENERATOR. — Henri Weiglé, Töss, Switzerland, assignor to Schweizerische Locomotiv- und Maschinenfabrik, Winterthar, Switzerland. In a gas-generator, the combination with the producer of an air-heater and a surface vaporizer in the upper part of the producer, both located in the path of the producer gases, said vaporizer and heater in communication with each other and with the producer below the grate thereof, and means to supply air and water to said heater and vaporizer respectively.

775,758. CENTRIFUGAL GAS-PURIFIER. — Frederick V. Matton, Riverton, N. J., assignor to Camden Iron Works, Camden, N. J. The combination, in a centrifugal gas-purifier, of a rotary fan, having blades with recesses in their sides, and a fan-casing having inwardly projecting lugs arranged in circular series adapted to register with said recesses as the fan rotates.

777,112. APPARATUS FOR CLEANSING THE GASES OF BLAST FURNACES, GENERATORS, ETC. — Emil Kratochvil, Kraluv Dvur, Austria-Hungary. In a gas-cleansing apparatus the combination of a suitable casing, a horizontal rotatable shaft through said casing, a series of disks on said shaft, a plurality of pins on the faces of said disks, a water-supply pipe, branches leading from said pipe having nozzles directed toward said disks, a water-outlet for said casing and gas inlet and outlets in said casing.

777,178. Apparatus for Removing Scale from Metal Rods. — Ernst Boley, Cleveland, Ohio, assignor to American Steel & Wire Company, Chicago, Ill. In apparatus for removing scale from metal rods and analogous articles, the combination of means for projecting comminuted material, a series of rollers mounted in planes transverse to the plane in which such material is projected, and means for drawing such rods under tension over said rollers and repeatedly through the zone of action of said projected material.

777,498. Blast Furnace. — John Coyne, Allegheny, Pa. The combination of a blast furnace having an outlet for the normal escape of gas, an explosion chamber connected to the furnace and means within said chamber for separating the gases from dust.

GREAT BRITAIN

25,248 of 1903. Iron Ore Briquettes. — T. Rouse and H. Cohn, London. The use of a solution of alum as a binding material for making fine iron ores into briquettes.

25,794 of 1903. Iron-Manganese Alloy. — R. A. Hadfield, Sheffield. An improved iron-manganese alloy for use in making manganese steel, having lower carbon contents than the ordinary ferro-manganese.

28,279 of 1903. Blast Furnace. — F. A. E. Samuelson and W. Hawdon, Middlebrough. Making blast furnaces with elliptical cross-section so that the blast shall penetrate the charge with less blowing power.

K. HERMANN WEDDING

SEE PAGE 270

The Iron and Steel Magazine

" . . . . . . *Je veux au mond publier d'une plume de fer sur un papier d'acier.*"

Vol. IX March, 1905 No. 3

THE DEFECTS IN INGOT-IRON CASTINGS *

By PROF. K. HERMANN WEDDING

Special Contributor to The Iron and Steel Magazine

IN Germany articles made of ingot iron, that is, of a malleable iron obtained in a fluid state, are called ingot-iron castings. On account of the name applied to ingot iron in other countries, these castings sometimes are termed cast steel, although the chief characteristic of steel, namely, hardening power, is often lacking and its tensile strength is also less than 50 kilograms per square millimeter.

Ingot-iron castings have the advantage over implements of weld iron of being free from slag, but they have the disadvantage of enclosing gases which form cavities upon solidification. Ingot-iron castings are superior to cast-iron castings, that is, to articles made of remelted pig iron, in possessing a far greater tenacity and in being forgeable.

Ingot-iron castings are generally made either in the open-hearth furnace or in the crucible, seldom in the converter. In general, one may assert that those which are cast from the crucible possess the best qualities, while those from the converter are the least desirable. This arises from the fact that the chemical composition of ingot iron can be more exactly regulated in the crucible than in the converter, and that the crucible process is the one by which the gases can be most easily

* Received February 13, 1905.

and most completely expelled from the iron, while in the converter process, whether acid or basic, this offers the greatest difficulty. In respect to the cost, the most expensive castings are those from the crucible, the cheapest those from the converter. It will be easily understood, therefore, that the middle way is most often chosen and the open hearth employed for the melting of the iron used for the manufacture of ingot-iron castings. Hence special consideration will be paid to this process in the following pages.

The defects in ingot-iron castings first of all are caused by the evolution of the gases, and it is necessary to investigate the causes of this evolution.

Blow Holes. — All carbonized iron can absorb gases. These gases are frequently united with the molten iron into a fluid alloy, but upon solidification they behave differently. They may (1) remain alloyed with the iron, (2) be retained between the crystals, (3) escape into the air if they be given the opportunity, or (4) remain imprisoned in the solidifying iron, forming small cavities or blow holes.

In general, the rule holds that the hotter the molten iron, the more quickly it will absorb the gases, and that the more quickly it solidifies, the more gases it will retain. The absorption of gases can, therefore, be avoided, or, at least, diminished by protecting the iron during melting from the influence of gases, *e. g.*, from air or steam, and by treating it in the same way when it is poured; or efforts may be made to expel the enclosed gases. For this reason crucible cast steel (iron remelted in the crucible) contains the smallest amount of gases. For this reason, also, drying the air which is blown in the Bessemer converter would be advantageous, and likewise, to keep out the hydrogen a layer of slag in the open-hearth furnace should be effective. Besides this, the molds must be filled so as to exclude air as much as possible.

Enclosed gases can be expelled by a slow cooling of the molten iron. This procedure is adopted both with crucible and open-hearth steel. Another means is the stirring of the molten iron.

Besides these means, which naturally effect only the expulsion of the gases not chemically united with the iron and not those alloyed with it, means may be employed which hinder the evolution of the gases by causing them to remain alloyed with the

iron. For this purpose silicon and aluminum are especially useful.

The gas most frequently enclosed and in largest quantity is hydrogen, and the two elements named act on it as just stated. Manganese, on the contrary, lessens the power of the iron to retain the gases, causing a quicker escape of the gases separating from it upon solidification.

Concerning the absorption of hydrogen gas, the reader is referred to the essay of the author in the reports of the fifth international congress for applied chemistry held in Berlin in 1903, and concerning the absorption of gases to his " Handbuch der Eisenhüttenkunde," 2d edition, Vol. I, pages 443 and 1131.

Since iron poured in a mold solidifies first at the contact with the mold, the escape of the separating gases is very soon prevented; and they form, as far as their tension permits, small cavities in the interior of the metal.

These cavities have sometimes smooth walls, when the solidification proceeds quickly, as, for example, in ingot iron (ingot steel) rich in carbon; sometimes streaked walls on which projecting tiny drop-like grains appear.

These blow holes are generally pear-shaped, rarely cylindrical or spherical. The first form is easily explainable. The gas separates first on the solidified crust and forces its way into the still pasty mass. This part becomes saturated more and more with gas, the pressure of which increases and the cavities will necessarily be elongated with their long axis perpendicular to the cooling surface.

The place of separation will depend upon the rapidity of the solidification; which, in turn, will depend, aside from the heat conductivity of the mold, on the temperature of the iron when poured. In " hot " poured iron, the cavities show on or near the surface. Some castings are, on this account, unsightly and worthless unless they be worked into shape, while they may be free from cavities in the interior and therefore are really of good quality.

In " cold " poured iron the cavities appear wholly in the interior. Those castings of which the interior is to be bored out, for example, gun barrels or car wheels, are purposely poured relatively cold.

The internal formation of blow holes by gases may be sufficiently well detected when the upper surface does not show a concave form, but a perceptible swelling which, with a moderate separation of gas, produces a convex surface, and with a more powerful separation of gas a scattering of the metal. In the latter case one may be certain that a slaggy casting full of holes, and even porous, has been produced. An ingot iron refined by an addition of silicon or aluminum never shows this phenomenon. On the other hand, an over-refined iron, especially one from the converter or one which was refined by an addition of manganese, is much inclined to this accident.

The steel maker will easily learn to avoid these defects by correct handling of the molten metal, by slow cooling and by the proper addition of silicon or aluminum. In the molten metal one may introduce, without decreasing its toughness, from 0.1 to 0.3 per cent of silicon; while the amount of aluminum should generally be only 0.03 to 0.05 per cent.

It is difficult to regulate properly the casting temperature, since there is a complete lack of measuring instruments for this purpose. My own efforts to invent a suitable instrument have so far failed, but I am still in hope of finding a satisfactory device.

Shrinkage Cavities. — Very different from the gas cavities are the shrinkage cavities, that is, those cavities or "pipes" which form unavoidably in consequence of the contraction of the iron on cooling. To be sure these cavities, when they occur in the interior of the casting, are filled with gas, usually hydrogen, but if no gases were present in the iron, gasless cavities would still occur. The gas present between the crystals of the iron is drawn into these cavities, because of the rarefaction of the air which they contain.

The shrinkage cavities occur especially where the iron remains longest in a fluid condition. If, on solidification, opportunity is given the iron to contract freely, no shrinkage cavities will be found, while if this opportunity be denied, one or more cavities must necessarily occur in the interior.

For the most part such inner cavities are revealed by a depression of the upper surface where this lies nearest to the cavity. Such depressions are especially found on the uncovered surface of the sinking head where the metal was poured in. These depressions are generally considered as a good indication of a

successful cast and it is assumed, if they are deep enough, that no gas cavities are present in the interior.

In general, that iron is most liable to such cavities which contains the most occluded gases; therefore open-hearth iron will suffer from this defect more than crucible iron, while it will be most pronounced in Bessemer iron; and on this account the latter will be least used for ingot-iron castings. Very essential, however, is the correct chemical composition of the iron in respect to carbon and other elements. If the ingot iron contains metallic oxides, the cavities are often filled with carbonic oxide, and this explains why those varieties of iron which are not sufficiently refined in the furnace suffer the most from the formation of cavities. Of course, the shrinkage cavities are the more dangerous the richer the metal is in gas, because the expanding gases prevent the depression of the crust. Hence it is evident that those means which check gas cavities, such as additions of silicon, aluminum and manganese, may also be applied to decrease the size of shrinkage cavities or pipes.

Small, rather evenly distributed cavities and pores, which are found between the crystals and become visible by means of the microscope after filing and polishing, are likewise to be attributed, in most cases, to the separation of the gases, which takes place in the solidifying and pasty condition of the metal so that they cannot escape. These pores are essentially harmless. Formerly, in the manufacture of ingot-iron castings they caused troubles, but they have now been overcome. An even distribution of these little pores is obtained by an even and strong pressure before and during solidifying. For this purpose liberal sinking heads should be employed or hydraulic pressure while the swelling may also be prevented by layers of sand and by covers which are provided with only minute openings for the escape of the air. These are means, however, which are employed more often in the casting of ingots than in other castings.

In order to lessen or avoid shrinkage cavities in ingot iron, the most certain means is the application of properly shaped sinking heads at those places where the shrinkage cavities would appear, that is, where the metal remains longest fluid; as from these the still molten metal flows into the weaker parts where it solidifies quickly. As soon as this flow ceases, cavities must

naturally be formed. Each part of a casting is to be considered as a sinking head for the part lying below it, and from this may be inferred the best way in which castings should be molded; that is, in such a fashion that the smaller cross sections are placed below and the larger ones above and the latter provided with effective sinking heads.

Concerning the proper molding of such pieces Paul Friem, of Neuberg, recently read a paper which appeared in the January, 1905, number of "Stahl und Eisen."* He says correctly: "The standpoint of most complete filling of the mold must determine that arrangement as the most favorable which permits the application of risers to all places where they are necessary. Whether the inclined or horizontal molds fulfill this purpose best will depend on the shape of the casting and the demands made upon it when in use." Friem showed by numerous sketches in what different ways certain castings must be molded.

The shrinkage cavities depend, however, not only on the form of the molds, but also on the casting temperature of the metal. The cavities, when they occur, are larger the hotter the metal is when poured. But even a relatively cold metal will give rise, especially in thin-walled castings, to the formation of cavities in the interior, because, by the quick solidification of the crust, the pressure of the fluid metal is prevented. Both reasons often work together. The thinner the walls of the casting, the higher the temperature must be and the more must sudden alterations of cross section be avoided, and conversely the choice of casting temperature must be determined by the proportions of the cross sections.

With the casting temperature is immediately connected the speed of pouring. The formation of cavities is less if the mold is filled slowly, because some pressure occurs even during the pouring. However, the danger arises with thin castings that the mold may not be filled completely, while with heavy pieces under too long an influence of severe heat the walls of the mold may suffer greatly. In general, one will prefer the formation of large cavities from quick pouring and try to make them harmless. Most harmless are those which occur in the middle of large pieces where they can be filled by pressure. If, at the same time, on the surface of the cast or on the riser a solid

* The present paper was already completed when this essay was read.

layer forms this must be broken in order to afford entrance to the metal poured in afterwards.

Gas Cavities from Other Sources. — Gas cavities can also arise from other sources, and one must distinguish between those which are due to the operation of pouring (air bubbles) and those due to the substance of the mold (steam cavities).

Air Bubbles. — If the metal be poured in a high stream, it carries air with it just as when water is poured with a high stream into a vessel. The air seeks to come to the surface and escape. If it is prevented, for example, by a small departure of the flowing metal from a perpendicular line into a horizontal one, or by spaces in the mold, the air gathers and either hinders the filling of the mold or remains enclosed in the metal. Such cavities may be avoided by two means: (1) by pouring with a low stream, (2) by a correct arrangement of the mold, in respect to the connection of all the higher parts with the outer wall by perpendicular risers.

Steam Cavities. — By steam cavities are meant all cavities produced by the development of steam or gases from the substance of the mold, hence not only by steam, but by carbureted hydrogen which develops from the carbon mixed with the substance of the mold, by carbonic oxide, etc. The cause of this development is the dampness of the mold. Cavities of that sort are avoided by the careful drying of the mold and the application of correctly placed channels wherever steam can develop, both on the outer mold and on the cores. To be sure the surest preventive against influences of that kind is a well-dried or baked mold, heated at least above 100° C., but success in producing good work may be obtained also in undried or unbaked molds, even in green sand; only one must always take care to provide for the escape of air and steam.

On the other hand, from excessive development of steam, damage to the mold and even explosions may occur and, therefore, undried molds can be used only for the manufacture of small and thin castings. The most favorable case is that in which the molds have such a temperature that the taking up of hydroscopic water is prevented. The rule is to make the molds of a mixture of unbaked and baked clay to which has been added graphite, coke or powdered wood charcoal. The substance used for the manufacture of crucibles for cast steel

has shown itself best adapted for the molds for ingot iron. This matter will be taken up again.

Surface Cracks are a very interesting, but very differently explained, phenomenon. When one has prepared a mold in the best possible manner, taken into consideration all the relations of shrinkage, and is certain of pouring without internal cavities, if upon stripping pieces of the mold are found sticking to the casting, one can be certain that under these pieces, when they are scraped off, will be found worm-like impressions in which the substances of the mold were imbedded, while otherwise a smooth surface appears. Generally these impressions are not deep so that the usefulness of the casting is not thereby impaired, but they make unsightly work. To be sure these surface cracks are often found in the same casting in which shrinkage cavities, not gas cavities, are present.

Their origin is ascribed to a gas pressure which arises from steam developed in the substance of the mold, since such markings never appear in castings poured into iron forms. They are said to occur most frequently when the substance of the mold is prepared from clay, baked clay and graphite, less often in those consisting mainly of quartz.

Since the shrinkage cavities are not produced by the separation of gases, and hence have in the interior no great counter pressure, a small pressure on the exterior can make impressions similar to these markings. The author is also of the opinion that this phenomenon is to be ascribed to the gases of the substance of the mold. Others explain them as due to the different solidification of the constituents of the iron, and in fact microscopic examination shows that on their edges the iron contains much pearlite and less ferrite, at least more pearlite than at a slight distance away. Hence one would explain these markings as a phenomenon of segregation; the elements remaining last fluid sinking deepest. In fact in the solidification of alloys, for example, tin and lead, one can at will produce similar phenomena. The fact that with sudden chilling and in castings in iron forms these markings are seldom or never produced, that they occur less often in molds of sand, most often in clay molds, may, of course, also be explained by the influence of the more or less sudden chilling. A very fimly made mold gives more cause to the occurrence of such markings than a porous

one; a high casting temperature more than a low one. Hilger attempts to trace the cause of these cracks merely to shrinkage, and thinks he can prove this, since in the casting of a plate provided with a rib, the cracks occur when the rib is underneath, but do not occur when the rib is on the upper side. It is possible that the phenomenon has not always the same cause. Thus the markings often appear on the upper surface of a casting which has a considerable breadth and is poured obliquely or only on the upper surface while on the lower surface nothing of the sort is to be seen.

Cracks. — Ingot-iron castings often show, after cooling, more or less fine cracks, which arise either in the mold or after stripping. In technical language the former are called "hot cracks," the latter "cold cracks," but both kinds run into each other. The cracks in the mold, hot cracks, are produced by the resistance of the mold to the contraction occurring during cooling; and their production is favored by great inequalities in the cross sections of a casting and by sharp corners.

Moreover, a metal which possesses great tenacity in a hot condition is less exposed to this evil than a red-short metal, for example, an iron with a high percentage of sulphur or of sulphur and copper. Although one attributes to phosphorus only influence on cold cracks, yet this element also gives rise to hot cracks, because it lessens the tenacity in a hot condition though in a less degree than sulphur.

According to the experiments of Friem, an ingot iron with 0.05 per cent of phosphorus is susceptible to hot cracks. In this respect one has taken into consideration the known properties of foreign elements on carbonized iron at different temperatures.*

Hot cracks, which, as said above, occur especially at projecting corners, are most surely avoided by the removal of all hindrances to contraction. For this purpose, after the pouring the resistance to the contraction must be lessened or removed by loosening the opposing parts of the mold.

Three methods may be pursued here: either the walls of the mold are made so weak at those places that they are broken by the contraction of the iron; or, immediately after the solidi-

* See the author's "Handbuch der Eisenhüttenkunde," 2d edition, Vol. I, pages 483 ff.

fication of the iron the opposing parts of the mold are knocked away; or the casting is chilled at these points by the application of water, of a piece of ice, or of cold iron, etc. Therefore, the accessibility of such points must be considered in the formation of the mold and the mold boxes must be correspondingly constructed.

The method of allowing the opposing parts of the mold to be broken by the iron is achieved by applying a soft material at those parts, for example, no burnt material, but a molding sand merely well dried, or thin plates of clay. Thus one may insert thin plates of clay between the spokes and the rim of toothed wheels, and leave free the intervening space though filled with loose material, in order that they may not be displaced, such as bits of stone, wood charcoal or brick. One may also make the molds, especially the cores, of material which is united by substances easily burned out by the heat. For example, the molding substance may be mixed with molasses, syrup and rye meal. In the application of all these methods, care must be taken that the mold remain uninjured by the mechanical action of the flowing iron; and the liquid metal must be so conducted that it does not strike at right angles against these parts, but touches them in a tangential or parallel direction.

In the application of the second method, *i. e.*, uncovering the danger points so that they may cool more quickly, one must proceed just as carefully. The correct execution depends almost entirely on the skill of the molder. If he uncovers too soon, the loss of the still pasty iron may result; if he uncovers too late, his aim will be defeated.

Cracks always arise at such places which remain longer fluid than their surrounding. A quick cooling may be obtained by the third method; for example, by means of water. This is the method most easily employed as shown by sufficient experience of the founder. At the proper points, channels are dug in the superfluous substance of the mold and water is poured in so that the iron will be quickly brought into the solid state. Besides, in the molds themselves, pieces of iron may be used, which being good conductors of heat, bring about a more speedy solidification. To be sure these inserted pieces of metal may cause damage. In car wheels which are cast in

iron forms in order to make the rim hard are often found, in consequence of the quick cooling, cracks at the axle. Hence one must see to it that a good quantity of liquid material is provided here in order to follow up the contraction. In general the rule holds, that wherever the formation of cavities may occur, the danger of cracking is greatest. A last method, little used, but recommended by Friem, is the use of clamps of tough iron with a high melting point, which hold the parts together. In this case, however, hot cracks may, nevertheless, occur without being visible to the eye.

After cooling the castings often warp, due to unequal contraction. This can only be avoided by an even cooling and the corresponding contraction of the form. For the same reason so-called cold cracks occur after solidification, which are likewise consequences of tensions which arise through unequal cooling of the casting. They differ from hot cracks generally by being thinner and having rough edges, while the hot cracks run in straight lines with smooth edges. They are also often hardly noticeable to the naked eye and appear generally only upon working the casting, but they frequently run clear through the cross section. Ingot iron rich in carbon is in this respect more susceptible than ingot iron poor in carbon. That is the reason why one obtains crackless castings more easily from the basic than from the acid furnace. The cause of these cracks, as well as of the hot cracks, may be due to an improper arrangement of the mold. However, it is often incomprehensible that in the cold castings tensions frequently remain which can be eliminated only by careful annealing.

In annealing also one must pay attention to the distribution of the mass both in heating and in cooling; otherwise both cold and hot cracks may again be produced.

Filling Defects. — The above observations show that it is not difficult and that it does not require long experience to avoid entirely defects in ingot iron, whether they appear as gas bubbles, shrinkage cavities or cracks. However, it often happens that a casting even after being completely cold shows a perfect outside surface, but on working it, cavities appear which fill the entire cross section, or cracks show which were not visible before. The question will now arise, Can and should one attempt the removal of such defects? I should like to answer the ques-

tion first of all by the statement that this should never be done without the consent of the purchaser, who certainly will not refuse his consent when it is merely a question of defect in appearance, but will refuse it if danger might result from it.

There is especially great danger in case of castings on the tensile strength of which demands may be made, because the form and the extent of the defects can seldom be judged from the appearance of the surface. Cavities are often pear-shaped, with their small end upward. Within their diameter increases and the shape can seldom be determined by instruments.

If the permission be given for filling the cavities or other defects, there are more or less effective methods for that purpose. Under all circumstances, before proceeding to fill a cavity, its surface must be carefully cleaned of all extraneous matter. Besides, the greatest cross section of the cavity must, if possible, be uncovered. Cracks must be dug out enough to get into them conveniently with the filling material. Before one applies any method whatever, the surface of the space to be filled should be brought to as high a temperature as possible.

Filling by Electric Welding. — The faulty casting may be corrected with one pole of an electric current while the other pole is connected either with an iron or a carbon electrode held near the casting and thus producing an electric arc. In case an iron electrode is used, this, itself, is melted, and it depends thus on the kind of the iron used how far its properties correspond exactly with those of the casting to be filled. If a carbon electrode is employed, a piece of iron must be melted in the electric arc. In the meantime the melted iron saturates itself with carbon and one obtains a filling which possesses less tenacity than the casting which is to be mended.

Filling with Molten Iron. — If a cavity or crack is to be filled by the same material, in a fluid condition, which served for the manufacture of the casting, it is more difficult than in electric welding to bring the piece first of all to a sufficiently high temperature. For this purpose, cast iron is usually employed which is poured over the defective part until it is brought to a welding temperature. Heavy pressure must be applied, and so over the part to be mended a mold is set, cylindrical in shape and so constructed that it has an entrance and exit channel in order that the fluid iron may flow constantly over the defect.

After some time this mold is filled and the iron allowed to solidify.

Filling by Thermit Treatment. — By treatment with thermit, that is, a mixture of iron oxide and aluminum which is burned, one obtains a relatively high temperature and can easily bring the piece to be treated to such a high temperature that welding is practically assured. To be sure the iron produced here is a pure iron and consequently possesses less tenacity and greater ductility than the iron mended. Moreover, the thermit treatment has become rather general for such mending purposes.

These three processes just described are used in common welding. They would fulfill their purpose completely if it were possible to determine exactly whether the spaces to be filled had been really brought to the necessary temperature. That this does not happen in a great many cases miscroscopic investigations prove by revealing a sharp line between the skin of the cavity and that of the added metal so that one must assume that a complete union takes place only in rare instances. It has been frequently attempted, since this phenomenon is attributed to oxidization, to apply certain fluxes, for example, to fill the cavities first with borax or silica; but this has the great disadvantage that one is not certain of having kept the surface free from slag.

Filling by Patching. — A last method for filling the cavities is as follows : Iron containing a very small amount of carbon and as pure as possible is brought to a welding temperature and then hammered into the cavity after this has likewise been heated. If the cavity in the interior is wider than on the surface, such patching never succeeds. A microscopic examination always shows the joint plainly and proves that this work does not achieve its purpose. In general, one may say that, without special order from the purchaser, this method ought seldom to be pursued, lest it be condemned as a fraud.

NOTES ON THE ETCHING OF STEEL SECTIONS *

By WILLIAM COBB SMEATON

Written for The Iron and Steel Magazine

BROADLY speaking, any process by which the micro-constituents may be differentiated on the polished surface of a metal or alloy is an etch. Four general classes of etches are to be distinguished: (1) Heat-tinting; (2) electro-deposition; (3) polishing in bas-relief; (4) solvent etches.

Heat-tinting differentiates the rate of formation of oxidation films over the surface of the various constituents. Electro-deposition differentiates the rate at which selected metals are deposited on the constituents through galvanic action. Bas-relief polishing differentiates the hardness of the constituents, while solvent etches practically differentiate their rate of solubility, and involve, as a determinative factor, the ultimate solubility.

Solvent etching agents comprise solutions of nitric acid, iodine, ammonium nitrate, picric acid, etc., as these are ordinarily applied in the various etching recipes, and include also those cases where the surface to be etched is made the anode in a bath of the solution (electro-etching). Chemical changes secondary to the solution process frequently take place. They are of great importance and are more or less regulated by the choice of etching agent and the conditions under which it is employed. Leaving these secondary changes out of consideration, there remain two factors that are involved in solvent etching. The one relates to the etching medium, the other to the polished surface.

As regards the former, attention must be paid: (1) to the chemical nature of the etching solution; (2) to the concentration of the active etching agent; (3) to the ultimate solubility of the constituents, particularly of the less soluble ones; (4) to the reaction velocity, which, in conjunction with the time factor, is of greatest importance.

On the other hand, the nature and condition of the polished surface affect the etch in several ways. The granular com-

* Contribution from the Chemical Laboratory of the University of Michigan. Received February 23, 1905.

ponents are cut by the plane surface of the section in different relations to their crystallographic axes, which may give rise to different colors on the same constituent through variations of the corrosion figures. None of the constituents are of invariable composition. Ferrite approximates the composition of pure iron, but may be α-, β- or γ-iron. Pearlite contains approximately 0.9 per cent of carbon. According to the views of most metallographists it is a definite mixture of ferrite and cementite in alternating plates or granules (lamellar or granular). Others hold it to be composed of slightly variable proportions of cementite and dilute solution of carbides in α-iron, according as the rate of cooling through the critical range Ar_1 is varied. Martensite is generally recognized as a solution of carbides or carbon or of both, in γ- or β-iron, the composition of which is variable between wide limits, about 0.2 to 2.0 per cent of carbon, while "hardenite" is applied to the solution when saturated with the solute. The conditions of saturation are not yet definitely established, hence the term "hardenite" should be used with caution. Austenite is regarded as a solution of carbon in γ-iron, usually being mixed with martensite or cementite. Sorbite and troostite * refer to transition stages between martensite and pearlite.

Apart from these components, which are dependent upon the relations between carbon and iron, there are left for consideration the existence of sulphide and phosphide areas, the possibility of phosphocarbides (Stead), and of double carbides of iron and manganese, etc.

The orientation of the constituents depends upon the mechanical and thermal history of the steel. In particular it is essential to have a complete thermal record, *i.e.*, the rate of cooling and the length of time a given temperature has been held. The grains are influenced according to the laws governing the deformation of crystals, resulting in twinning, slip bands, surface flow, etc.†

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* According to Boynton, "J. Iron and Steel Inst." (I), 1904, 262, troostite is β-ferrite.

† E. Heyn, "Zeitschr. des Vereins d. Ing.," 44 (1900), 433, 503. Ewing and Rosenhain, "Phil. Trans.," 193 (1899), 353. G. T. Beilby, "J. Soc. Chem. Ind." (1903), 1166; "Proc. Roy. Soc.," 72 (1904), 218; "The Electrochemist and Metallurgist," 3 (1904), 806.

The segregation of a given constituent is correlated with the heat treatment. The increase of grain area through overheating mild steel, the transformation of lamellar pearlite into the granular variety by reheating to between 450° C. and Ar_1 fall under this head. On holding an annealed tool steel, containing 1.28 per cent carbon, for 24 hours just below Ar_1, practically all of the well laminated pearlite became granular. The diameter or many of the rounded areas was remarkably large, from 20 to 30 microns. While most of these were massive cementite, as would be expected, nevertheless some scratched readily with a needle and were ferrite. These larger ferrite areas could only have come from smaller granules through the influence of surface tension.*

Solvent etching agents attack solid solutions most rapidly, and in proportion as the concentration increases. Cementite is most slowly acted on, while ferrite is slowly dissolved by the common etching agents, much more rapidly by solutions of the ammonium salts of strong acids and by solutions of persulphates. Furthermore, α-, β- and γ-iron are attacked at different rates by the same reagent.†

Quite apart from the nature and orientation of the constituents, the condition of the polished surface has an important bearing upon the resultant etch, no matter what the class of the etch may be. This point seems to be not generally recognized by metallographists.

Beilby ‡ has demonstrated that mechanical work, in the shape of the friction involved in polishing, produces surface flow on metals, which results in the formation of a surface film, differing in nature from the mass of the metal. From Beilby's

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* Compare Spring, "Zeitschr. f. phys. Chem.," 15 (1894), 65. Heycock and Neville, "Proc. Roy. Soc.," 69 (1901), 325.

† Carl Benedicks, Doctor's Thesis, Upsala (1904). "Recherches physiques et physico-chimiques sur l'acier au carbone," pp. 180 and 196. Dr. Benedicks distinguishes β-ferrite in steels with more than 0.5 per cent of carbon, as "ferronite," and regards ferronite as a dilute solution of carbide in β-iron, containing not more than 0.27 per cent of carbon.

‡ G. T. Beilby, Brit. Ass. Report (1901), 604; "J. Soc. Chem. Ind." (1903), 1166; Proc. Roy. Soc., 72 (1904), 218; "The Electrochemist and Metallurgist," 3 (1904), 806. Compare also, Spring, *loc. cit.;* Ewing and Rosenhain, *loc. cit.;* Osmond, Fremont and Cartaud, "Revue de Metallurgie" (1904), 11.

researches it is evident that a remarkably small amount of mechanical work causes a noticeable alteration of the surface, especially in the case of iceland spar and other crystals.*

Whatever be the technique of the polishing operation, it produces a surface film which must be removed by the etching agent before the micro-structure can be developed. The drastic polishing procedure with carborundum, which is employed in this laboratory,† frequently results in very pronounced films at the hand of inexperienced operators.

Furthermore, rouge always leads to the formation of pronounced films when applied wet. This point is of importance in America, where the tendency to obtain results quickly by utilizing polishing surfaces at high speeds is much in evidence. The excessive amount of water required to keep the section cool and thus avoid oxidation films is incompatible with the use of rouge. I have spent from two to three hours trying to polish a very soft steel with rouge on a high-speed wheel, but have never succeeded in avoiding a bad case of surface film. By using alumina ‡ an hour's polishing gave a satisfactory surface with a scarcely noticeable film. Alumina remains uniformly suspended in the water during polishing, while rouge cakes. Different samples of rouge have been thus tested in this laboratory and all act in the same way.

Evidences of surface flow were often brought to my notice before I knew of Beilby's investigations and they were the cause of serious difficulties at first. Sections may be apparently satisfactorily polished, yet on being etched they reveal a mass of furrows where the etching agent has a drastic action, while with milder etching agents the entire surface appears to be uniformly attacked. This has happened over and over again, particularly in cases where it was desired to produce a light etch. Sometimes the flow is so much in evidence that the granular structure is developed underneath a slightly yellowish skin.

Aggravated cases like the above indicate a lack of skill on the part of the operator, and they invariably occur with students

* Beilby, "Electrochemist and Metallurgist," 3 (1904), 818.

† This Journal, February, 1905.

‡ See Le Chatelier, "Bull. de la Soc. pour l'Encouragement de l'Industrie Nationale" (5), 6 (1900), 315. Osmond and Stead, "Microscopic Analysis of Metals," p. 68.

carrying on polishing operations for the first time. They may be avoided, even when carborundum is used, but with wet rouge are always pronounced. A thin film is never avoided, but does not interfere with the etch. Too great stress cannot be laid on the preliminary polishing operations. It not only saves a good deal of time on the rouge or alumina wheel, but also lessens the possibility of the etched section revealing a mass of furrows, to exercise special care with the first operations on the coarser wheels.

Surface films are responsible for many of the recorded failures to produce etches with well-known etching agents. The ease with which they form varies from one steel to another and with the heat treatment. The polishing technique is capable of development to such an extent that even under the most unfavorable conditions serious cases of film formation are easily avoided.

The relations established between surface films and solvent etches apply equally to the other classes of etches. I have had time for only a few experiments concerning surface films and heat-tinting. Some reagent should be found to remove films without producing more than a very light etch. Up to the present 2 per cent H_2SO_4, acting at 60° C. for two minutes, has given the best results. The surface must be carefully washed and dried after treatment with the reagent. Experiments on electro-deposition have not been carried out. As regards polishing in bas-relief, Osmond's method of polish attack with licorice or ammonium-nitrate bears upon this relationship and will be considered later.

Beilby, in the last article quoted, offers an explanation of surface films, and remarks that the ease with which they are removed stands against his explanation. It is pertinent to state also that they give indications of homogeneity upon etching, and that the rapidity with which they are attacked by ordinary reagents indicates that they are solid solutions, probably of oxides of the metals. This assumption will satisfy all of the experimental data adduced by Beilby.

Osmond gives a great deal of practical information concerning the influence of the nature of the etching solution. In a preliminary report of experiments carried on in Le Chatelier's laboratory, Kurbatoff * states that the rapidity of the etching

* V. J. Kurbatoff, "Proc. Russ. Chem. Soc.," October 7, 1904.

action of nitric and picric acids in water and various alcohols is approximately proportional to the associating power of the solvent and to the degree of electrolytic dissociation of the acid. In this laboratory we have demonstrated qualitatively that the etching action is approximately proportional to the degree of electrolytic dissociation of the active etching agent in the case of water solutions of nitric acid, ammonium nitrate, etc. We have adopted the expedient of altering the electrolytic dissociation by adding an indifferent substance with a common ion, *e.g.*, potassium or sodium nitrate with nitric acid, etc. These experiments are still in progress and discussion of the results is reserved. This expedient gives a means of adjusting the concentration of the active etching agent very minutely.

Another means of adjusting the concentration of the active etching agent minutely is afforded by using aqueous solutions of the ammonium salts of the strong acids. Experiments were made with hydrochloric, sulphuric and nitric acids and their sodium, potassium and ammonium salts. Solutions of the potassium and sodium salts are without noticeable action, either at room temperature or at higher temperatures. The ammonium salts have an etching action which increases with the concentration of the salt. At room temperature the action is less vigorous than at higher temperatures. Furthermore, the etched surfaces present the same appearance that they have when etched with dilute solutions of the respective acids. Ferrite appears to etch rather more easily with the ammonium salts than with the free acids. The time required for an etch varies from five to fifteen minutes, according as the temperature and concentration are altered. With very concentrated solutions, however, secondary reactions take place which vitiate the results.

All these solutions of the ammonium salts of strong acids have an acid reaction, owing to hydrolysis. The extent of the hydrolytic dissociation increases with the temperature in each case studied. The active etching agent is thus the free acid arising from hydrolysis. Apparently the ammonium ion tends to form ammonium complexes with the product of the reaction between nitric acid and iron, when concentrated solutions are employed. Two per cent ammonium nitrate has been found most satisfactory.*

* Compare Osmond and Cartaud, "The Metallographist," 3 (1900), 1.

The action of persulphates has also been studied. At room temperature aqueous solutions of potassium and ammonium persulphate have an etching action. Persulphates attack ferrite more readily than other reagents and are without action on cementite. Experiments are now being carried out with the view of utilizing persulphates as reagents for the different ferrites.

The influence of reaction velocity has been taken into account in all of our etching experiments. The importance of this point, while doubtless generally recognized by metallographists, seems to be not sufficiently emphasized in the literature. As a rule no mention is made of temperature in the various etching recipes applied by different workers in this field. Fused calcium chloride at 900° C. has been recommended by Saniter * as a reagent for γ-iron, also gaseous hydrochloric acid at suitable temperatures. Osmond † calls attention to the same point in connection with etching γ- and β-iron. He also speaks of etching with 1.4 sulphuric acid at 50° C.‡

The relations between reaction velocity and temperature have been established by physical chemists. In most cases rise of temperature increases the reaction velocity. While the character of the reactions taking place during solvent etching is not definitely established for all the constituents of polished steel surfaces, it is safe to assume from analogy that they are for the most part increased by rise of temperature. Now a rise in temperature of ten degrees Centigrade approximately doubles the rate of reaction in such cases.

I have used aqueous solutions of different acids and salts at various temperatures between room temperature (about 20° C.) and 90° C. In all cases the results have accorded with my expectations, and this method of applying the etch at slightly elevated temperatures is proving invaluable.

I place the solutions in small crucibles and heat them in an air bath. The temperature is easily regulated by an ordinary thermometer to $\pm 0.5°$ C., which is sufficiently close. The sections are immersed in the solutions and the immersion is carefully timed. In this way it is possible to use very dilute

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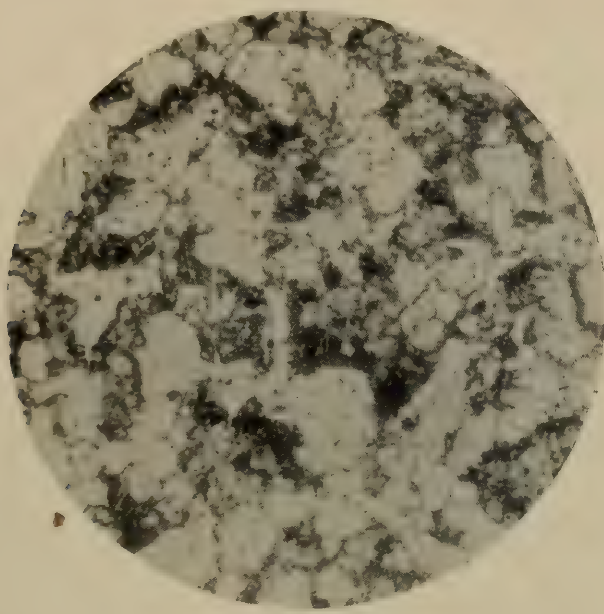
* E. H. Saniter, "J. Iron and Steel Inst." (1897), II, 115; (1898), I, 206.

† Osmond, "The Metallographist," 3 (1900), 276.

‡ Osmond, *loc. cit.*, p. 280.

reagents, in case surface films are not too much in evidence, and, although the time may be prolonged for fifteen or twenty minutes the etch is always distinct. Obviously, this method is specially applicable for observations under high magnifications. By suitable choice of etching agent and temperature, it ought to be possible to distinguish the different forms of ferrite, etc. Experiments with ammonium nitrate on very mild quenched steels indicate that β-iron is more rapidly attacked than α-iron, in agreement with Benedicks.* Furthermore, delicate distinctions between double carbides, phospho-carbides, etc., ought to be detectable in this way.



The case of a low carbon annealed steel, of which the microconstituents are α-ferrite and pearlite, will serve to illustrate the influence of reaction velocity. Assuming that the rate of attack of two per cent nitric acid at 20° C. is expressed by 0.1 for ferrite, then at 30° C. the rate of attack is 0.2, and at 40° C. it is 0.4, etc. Thus by increasing the temperature only 20° C., the reaction velocity has been quadrupled.

With respect to Osmond's method of polish attack with two per cent ammonium nitrate, it is evident that free nitric acid is the active agent and that the friction raises its temperature, thereby increasing the hydrolysis and the reaction velocity

* Benedicks, *loc. cit.*

simultaneously. I find 40° C. the most suitable temperature for etching with two per cent ammonium nitrate. The accompanying photograph illustrates this etch on a steel containing 0.31 per cent carbon, quenched from 740° C., magnification 118 diameters.

IMPROVEMENTS IN THE MECHANICAL CHARGING OF THE MODERN BLAST FURNACE *

By DAVID BAKER

OUR large modern blast furnaces, equipped with ore-bins, larries and mechanical means for putting stock into storage, withdrawing it therefrom, and charging it at the tunnel-head, are indeed wonderful in capacity; yet it is admitted that, with some notable exceptions, they have disappointed us in economy — that is, in the items low fuel consumption, uniformity of product, freedom from slips and reduced cost of repairs and relining.

The modern stack tends to work irregularly; slips are too frequent, and too much "off"-iron is made; the furnace "swings" too often and too much. I think it is this irregular working that causes the greater fuel consumption; and according to experience, when a furnace begins to work irregularly, one of the first things to be examined in searching for the cause is the distribution of the stock on top.

From a faulty distribution comes a great train of evils: higher fuel consumption, irregular work, slips and rapid destruction of the furnace lining. Correct the distribution and diminish the breakage of coke, and the modern stack will do better work in every particular than the older hand-filled furnace, yielding a fair return for the money invested in labor-saving appliances.

After long investigation of the mechanical filling of blast furnaces, I am satisfied that it is impossible to obtain a satisfactory distribution of the stock with the double-bell charger and dumping skip, however varied with deflectors, adjustable chutes, reducing hoppers or any other mechanism depending for adjustment, etc., upon an operator.

*American Institute of Mining Engineers, September, 1904. Abstracted.

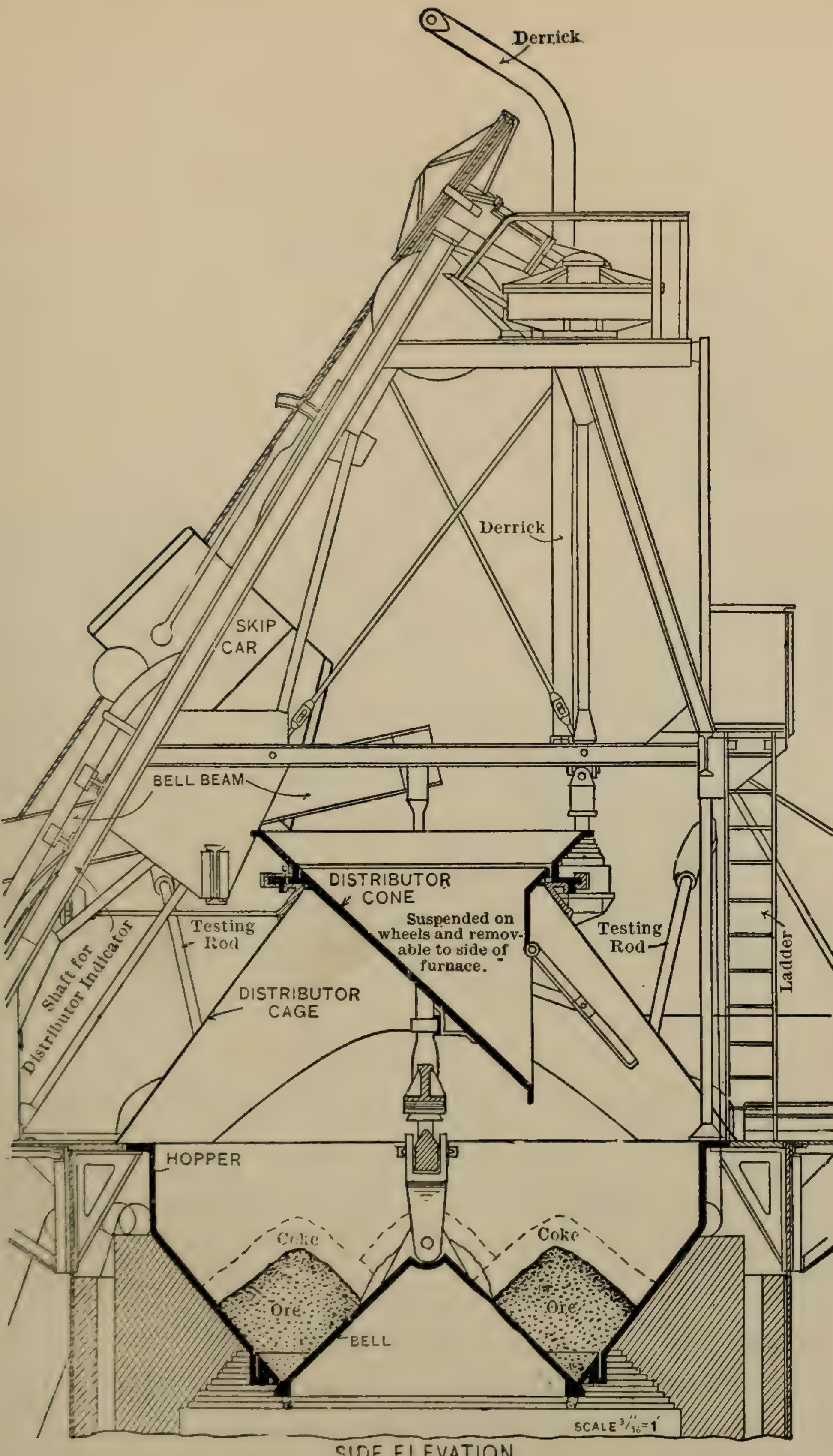


FIG. 1. A Distributor and a Double Skip

In searching for some means of duplicating hand-filling mechanically, I concluded that, since the skip could not readily be rotated about the furnace top, like the barrow in hand filling,

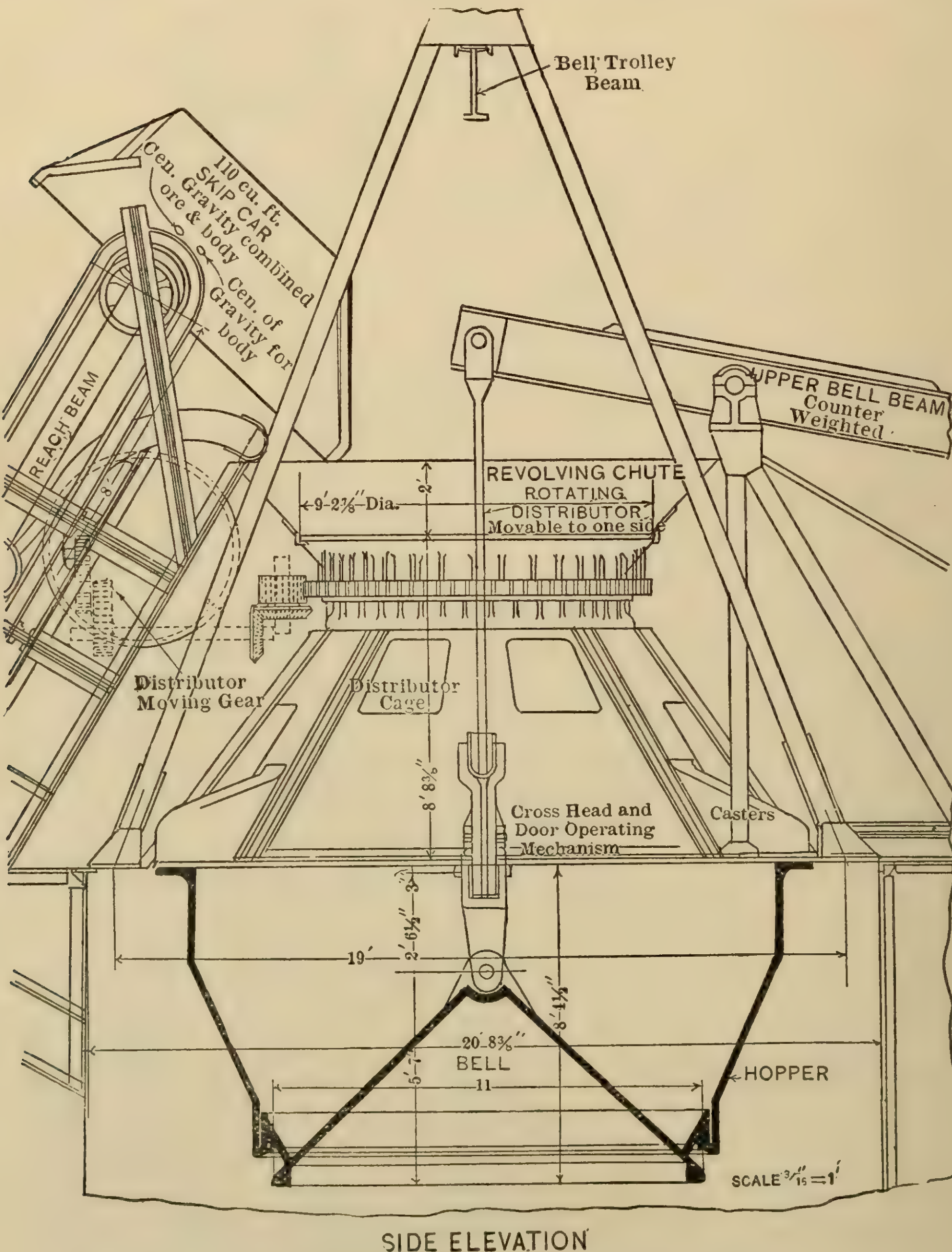


FIG. 2. A Distributor and Single Skip with a Double Bell-Rod

we must try to rotate the furnace top so as to produce the same effect — in other words, to obtain the advantages of hand filling, and avoid its disadvantages, by making an automatic arrange-

ment, working in unison with the skip hoist, and not dependent upon an operator.

The top, invented some years ago by Alex. E. Brown, of Cleveland, answers all these conditions. Here a revolving hopper is operated by the skip hoist-rope wheel. This hopper, provided with a wide chute, is moved into position while the empty skip is descending, a ratchet arrangement in the drive preventing any movement in an opposite direction. This device, which may be used with single or double skip, directs each skip load into a different section of the hopper. For instance, the coke charge may be sent up in four skips and deposited in four equi-

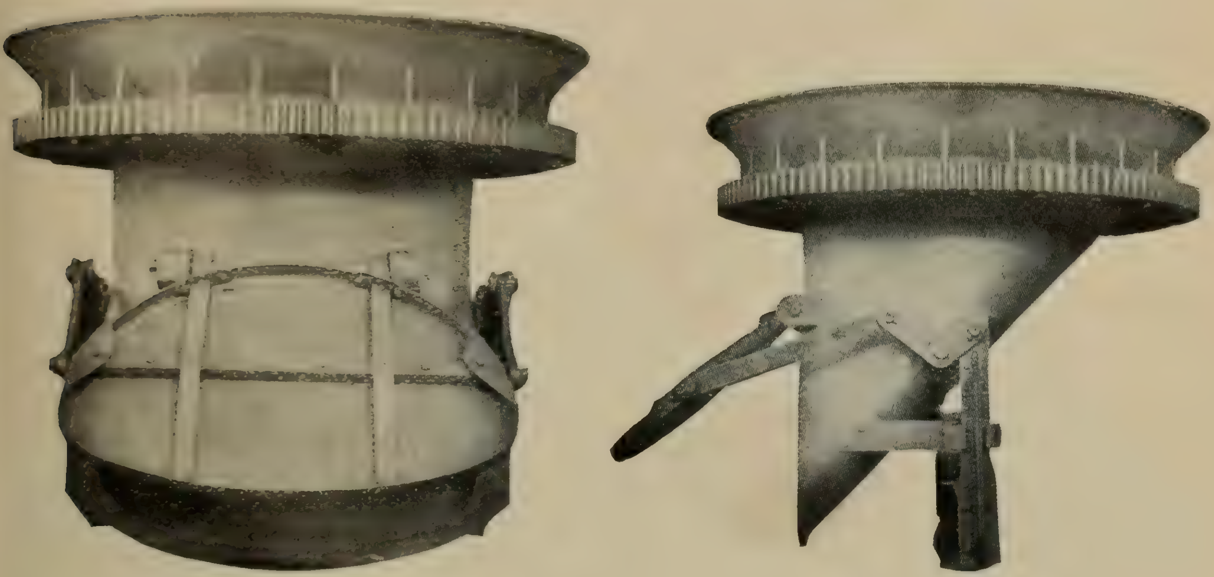


Fig. 3

distant parts of the hopper, thus making, owing to the wide discharge nozzle, a complete ring of coke in the hopper. After the coke has been lowered into the furnace, the ore and limestone are sent up in the next four skips, thus making a complete ring of ore and limestone in the hopper. Now to make this arrangement even better than hand filling, this hopper, instead of moving just 90° between skip loads, is moved, say, 4° more, so that the material of one charge is dumped in a slightly different place from the same material in the preceding charge. Thus, if 8 skip loads make a complete charge, the first ore of one charge will be dumped at a point 32° from that of

the first ore of the preceding charge, and so on. It is this indeterminate feature of the distribution which makes the apparatus valuable.

The breakage of coke or ore is relatively small, for the hopper chute is kept as close to the main hopper as possible, and this distance may be cut down below ten feet.

This charger was patented before the mechanical filling of blast furnaces became the general practice; and the furnace managers of that day, while recognizing almost universally the theoretical value of Brown's invention, thought it involved too much mechanism for a blast furnace, and the double bell, by virtue of its simplicity, became the most common type. Now, however, the serious defects of the double-bell charger have been demonstrated, while on the other hand Brown's device has been simplified. Fig. 1 shows its present form for the single skip, with the double-bell rod. The whole of the gas seal and distributor is on wheels, and can be jacked up and run to one side, as shown by dotted lines in the figure, when repairs must be made to the main bell and hopper,

The gas-seal door is open, except when the bell opens. Then the first three inches' travel of the main bell allows the door to drop shut, and the top is sealed. During charging, the door, being open, allows the stock to flow freely out of the chute and gives a more uniform distribution in the main hopper.

Fig. 2 shows the distributor applied with the double skip. No superstructure is required over the top of the furnace except what is necessary to handle the bell for repairs.

Fig. 3 shows the revolving hopper or chute removed from the gas-seal cage and support.

Fig. 4 shows the gas-seal cage, which is made of reinforced steel plate in this case, but is sometimes made of cast iron where preferred.

In the earlier forms the revolving hopper was supported on wheels, and later on steel balls. In the present form all these are dispensed with, and the flange of the hopper simply slides at the top of the gas seal, on a surface of cast iron against cast iron, about eight inches wide, and lubricated only with graphite. This arrangement, contrary to prediction, has been found to show practically no wear after a year's use. If they will last through a blast, the arrangement will have served its purpose

well; and it seems, under actual trial, to be entirely capable of that degree of durability.

The flue dirt does not seem to enter the joint to any extent. I believe the reason lies in the fact, already noted, that the gas-seal door is only closed when the main bell is open.

The pressure on the sliding surfaces is only about ten pounds per square inch, and the friction under that load cannot be great.

This distributing top has passed beyond the experimental stage and has shown itself in practice to possess the advan-

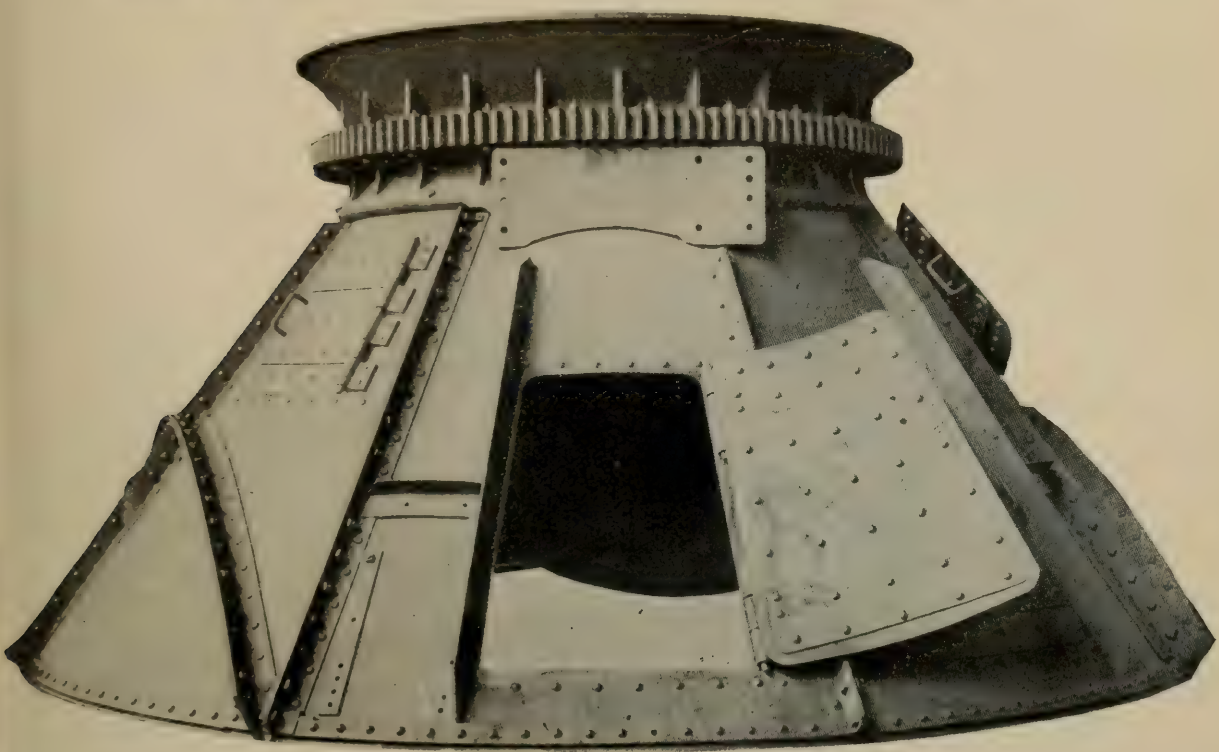


FIG. 4

tages, without the disadvantages, of hand-filling. In all the furnaces where it has been installed it has reduced the slips and prevented the irregular wear of the in-wall. There are indications that it will show a marked saving in fuel; but the data for comparison in this respect are not yet sufficiently complete for publication.

If the present prospect of technical efficiency should be confirmed by longer use, only one further improvement will be required to secure results superior in economy to those obtained by hand charging — namely, an arrangement of bins and

apparatus for handling coke which will do away with the excessive production of dust involved in present methods of storage and rough handling and rehandling of this fuel. This subject has been treated in my paper on "Stock-Distribution." *

DRY AIR IN THE BLAST FURNACE †

ON the 23d of last October Mr. James Gayley, president of the American Institute of Mining Engineers and vice-president of the United States Steel Corporation, read a paper before the Iron and Steel Institute on the use of dry air in blast furnaces. To refresh our readers' memories, we may say that Mr. Gayley, for experimental purposes, supplied a large blast furnace with air dried by cooling it so that it deposited its moisture, and he claims to have very greatly increased at once the output of the furnace and its economy. The saving in coke per ton of iron made is about 20 per cent. This remarkable paper has received at least as much attention in France as in the United States or this country; and the last number of the "Bulletin de la Société d'Encouragement pour l'Industrie Nationale" contains two critical articles on it, the one by M. Ch. E. Heurteau and the other by M. H. le Chatelier, which deserve careful consideration.

Neither of these eminent authorities is prepared to accept Mr. Gayley's statement as in any sense complete. Neither believes that the thermodynamic effect of excluding water can produce a saving of anything like 20 per cent. M. Heurteau mentions the reduction in volume of the air as one source of economy. For the rest he criticises American general neglect of economy in ironworks and hints that if the system can be worked to advantage in America, it ought to give still better results in more careful and scientific French hands. M. le Chatelier writes at much greater length, and is far more severe in his criticisms. He asks three questions: First, Are the results announced exact? Secondly, Can they be reproduced in France? Thirdly, What is the cause of the results? As the

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* *The Iron and Steel Magazine*, April, 1904.

† "The Engineer," January 20, 1095.

honesty of Mr. Gayley is unimpeachable, errors can only be those of observation or involuntary mental bias. Yet there are inconsistencies which demand explanation. Why, for example, was the temperature of the blast raised from 385° C. to 465° C.? Was it because the stoves had been cleared of dust for the experiment? He then points out that the conditions are very much the same naturally in winter as they were made artificially in summer. But in regular work no such difference as 20 per cent, or anything like it, distinguishes the winter from the summer consumption of coke. As to whether the system will or will not give the same results in France as in the United States, M. le Chatelier reserves the expression of opinion, because so much must depend, he thinks, on the nature of the ore, the quality of the coke and the kind of iron made. The last question is that which possesses most interest for us. Assuming that an economy is effected, what is the cause of it?

He begins by pointing out that the removal of 6 grams of water per cubic meter of air could not represent a saving of more than 3 per cent, instead of the 20 per cent named by Mr. Gayley, and he goes on to expound the theory that less coke suffices because sulphur is got out of the pig. With dry air the sulphur surrendered by the coke burning before the tuyères is at once seized by the lime in the charge, and cannot gain access to the iron sponge farther up in a colder zone. When, on the contrary, water is present, the absorption of the sulphur by the lime is not complete, because of the presence of hydrogen. Divested of complication, this apparently means that the combustion of the sulphur must produce part of the heat required for the reactions, or else that, because the sulphur is taken up in the lime, the reactions are simplified, and it becomes possible to work the furnace at a lower temperature, and, therefore, with less coke. M. le Chatelier is not dogmatic; indeed, he goes on to point out that the question at issue can only be solved in France by a costly experiment.

It will be seen that the eminent French metallurgist has not referred in any way to two facts of the utmost importance to which we think it advisable once more to draw attention. The first is that no water can possibly find its way to the tuyères. The moisture in the air is all of necessity converted into highly superheated steam in the Cowper stoves. Assuming that dis-

sociation takes place, then a small quantity of hydrogen and oxygen will get into the furnace. How is it possible that any reaction between this hydrogen and the sulphur of the coke can reduce the coke consumption by 20 per cent? If it does, then we must modify all our notions concerning thermal efficiency; and the chemist is bound in fairness to give a definite statement of the reactions which take place within the furnace in the presence of a minute percentage of superheated steam in the neighborhood of the tuyères. Furthermore, it is clear that large quantities of water enter the furnace with the ore, and also with the coke. What is the reason that this water plays no part of importance? Is it that it is only at or about the tuyère zone that hydrogen can do mischief?

The second fact is that which we have already advanced as the explanation of the whole gain. It is that the weight of air sent into the particular furnace concerning which Mr. Gayley wrote was much increased by reducing its temperature. It would seem that the facts are not fully grasped. Let us suppose, to exaggerate the circumstances and make them more readily comprehensible, that the weight of air per cubic foot at normal temperatures was just twice what it really is per cubic foot, the pressure remaining the same. It follows that blowing engines of a given size would for the same horse-power deliver the same volume of air as they do under existing conditions, but the weight of oxygen sent into the furnace would be doubled. Now, the volume of the air in a furnace signifies nothing, the weight of oxygen everything. Again, let us suppose that the ports and passages in a stove are too small. As the volume of air delivered would remain unaltered, these same contracted ports would now pass twice the weight of oxygen they passed before without throwing any extra load on the blowing engines. The result would be in the main that the efficiency of the blast furnace would be doubled. But it is well known that various sources of loss remain constant, no matter what the rate at which the furnace is worked. The bigger the output, on the whole, the less will be the cost of fuel. Now the Isabella furnace, the subject of Mr. Gayley's experiment, was obviously, on his showing, doing badly. The output was small for so large a plant; the stoves were wrong in the matter of ports; the engines were overdriven to get air enough through the tuyères. All the

conditions were just those under which an increase in the density of the air would be of most use; and the cooling of the air — not the drying — augmented its density. One immediate result was, as shown by Mr. Gayley, that the engines had to be reduced in velocity. In all this, however, we see no particular promise that results anything like so good can be obtained with other furnaces working under more favorable normal conditions.

The whole question is far too important to be left in its present condition of incertitude. It is the bounden duty of the metallurgical chemist to set forth clearly the part which a small quantity of steam gas can play in a blast furnace. To us and to many others the end seems out of all proportion to the means. Our own explanation is purely mechanical. It suggests the reduction in the volume of air per pound of oxygen as the reason why Mr. Gayley got his furnace up to a normal output. It is not in any way clear that the coke per ton of iron was less than will suffice in other and better furnaces under ordinary conditions. This and many other points must be cleared up before it is possible to attach its real value to Mr. Gayley's invention.

MODEL TESTS FOR STEEL *

THE recent meetings at the Institution of Mechanical Engineers have brought prominently to notice the employment of shock tests for the testing of steel and the circumstances in which their use might be extended. Although steel almost, if not quite, monopolized consideration, similar tests for other materials would probably have led to equally interesting results. The type of test referred to is that in which a small sample of the material is formed into a rectangular beam and broken by a series of blows; or by one smart blow delivered either at the center or at one end, depending on the method of support. It is then concluded that in the one case the number of blows sustained is a measure of the quality of the steel; and in the other that the kinetic energy lost by the falling tup represents that necessary to produce fracture, and therefore in its turn the degree of excellence of the material.

* "The Engineer," December 30, 1904.

Before this subject can be considered to advantage it is necessary to get clear ideas as to the objects of testing materials at all. An engineering structure of some sort or shape requires to be constructed. It will when in use be stressed by certain efforts, some due to static loading and some to kinetic. It is desired that the structure shall be so proportioned, without however raising prohibitively the initial cost, as to endure the severest form of loading to which it could possibly be subjected in its ordinary work. Obviously the only direct way of making certain of this is to build a similar structure and load it till it fails. This, however, is expensive, and in practice the endeavor is to arrange that models only shall be tested to destruction. In the case of, say, a bridge structure of the usual type, a cylindrical steel rod stressed by a longitudinal force is an accurate stress model of the tension members of the bridge, and imagination sees in the testing machine a reproduction on a small scale of one of the bridge ties. By moving the handle of the testing machine, a whole lifetime of experience can be reproduced on a small but accurate scale. This is a case in which testing by means of stress models may be said to be thoroughly satisfactory; it owes its favorable position largely, of course, to the fact that it is the essence of the bridge designer's skill to permit of the existence of only the simplest forms of stress.

This simple kind of testing in the ordinary testing machine has occupied so large a place on the mental horizon of engineers that it has obscured somewhat the principle that all stress models must accurately and faithfully represent to scale the stresses which occur in the finished article; and that stresses of a simple nature in the model will prove useless as a guide to what occurs in the complete structure when complicated systems of stressing arise. In a stationary high-speed steam or internal combustion engine, stresses which are produced by the equivalent of blows, in that they are violent, sudden and of short duration, are the most important considerations in design, and it is beginning to be understood that mere tensile tests provide very inadequate information. It is safe to say that an engine designed to withstand static tensile loads alone would be a very unsatisfactory machine. As another case, cast-steel wheel centers may be taken. Here ordinary engineering practice demands the testing not of models only, but of the actual castings themselves. The

usual tensile tests are not omitted, it is true; but with the realization that ordinary tensile test specimens form most inadequate stress models of what occurs in the life history of a wheel center, drop tests are made of the castings themselves. In many other cases not only is the finished article stressed, but it is stressed to destruction. Naturally in such cases only a small proportion of the materials get tested at all. Even so, the procedure is an expensive one, however necessary it may be in the light of existing methods. On grounds both of economy and general convenience, it would, therefore, be a great advantage if testing on the scale of a model could be substituted.

In their recent paper read before the Institution of Mechanical Engineers, and published in our columns, Messrs. Seaton and Jude made known the very interesting results which they had obtained after carrying out a number of such tests. The specimen they used was a short beam of rectangular cross-section, slightly nicked in the middle. It was supported at the ends, and a blow was given to the center by a falling tup; this was repeated until the specimen broke, and the number of blows so delivered was taken as an index of the quality of the material. Many such tests were made, and curious anomalies were found. High tensile steels of proved ductility were shown to be quite brittle under shock tests; others, apparently similar, stood the same tests well. Doubt — grave doubt — was thereby thrown on the validity of using tensile tests as a guide in the selection of materials intended for use in machinery liable to shocks or blows. At the meeting of the Institution on December 16, further discussion took place, and a shock-testing machine of a somewhat different form was shown. In it the specimen received one blow only, one more than enough to fracture it; moreover, the specimen was held at one end only. If the specimen were struck with a sweeping blow close to the vise it would be little more than the shearing force that would be measured; if at the end, the bending would probably lengthen the blow so much as almost to remove shock effects. In any case it is undoubtedly advisable, and this was emphasized by many speakers, that the machine and specimen should both be standardized as soon as possible, subject, of course, to sufficient consideration being given to the subject to save hastily made conclusions from being adopted. It is almost impossible to

compare effectively shock tests carried out on different machines or in different circumstances. Values found by methods of inter- or extra-polation are rightly looked upon with the greatest suspicion.

As in their lifetimes finished structures are not subjected to one shock or blow only, it would appear advisable, having regard to the ideas underlying the testing of stress models, that specimens should be broken with a series of blows rather than by one only. It would be quite easy to devise a machine which would automatically deliver sufficient blows to break the specimen, register the number of them, and then feed in a fresh specimen. The form of specimen, the notching or screw-cutting, the effect of holding the specimen at one end only, and other matters, all require and should receive the most careful consideration. The effect of notches or scratches on specimens or finished articles as affecting their ability to withstand stress is not at all understood. A not dissimilar case is that of a shaft stressed by torsion, in which a keyway has been cut. The investigations of a celebrated mathematician seemed to show that the effect of cutting a keyway must be to reduce gravely the torsional strength of a shaft. It has, however, since been shown by another mathematician, in the light of fuller knowledge, that the effect has been greatly exaggerated, and that although it is true that at the sharp corners of a keyway the stress becomes infinite, yet, on the other hand, the area affected is infinitely small, and the tiniest amount of plastic yielding at the corners is enough to prevent any ill effect.

To follow exactly what occurs when a small beam specimen is broken by a blow at its center is certainly difficult. Immediately the blow is given, or begins to be given, a semi-spherical elastic disturbance spreads out in wave form from the point of impact. This wave of compression is reflected on reaching the opposite boundaries, and a complicated kind of shiver travels through and along the specimen. At the same time, secondary disturbances spread out from the points of support. The shivering rapidly dies away, and the resistance offered to further deformation becomes what is known as static. Obviously a great deal depends upon whether the tup "gets in" its blow before the shivering has stopped. Having regard to the velocity with which sound travels in a steel rod, probably it does

not, and the phenomenon becomes simply that of a series of static forces rapidly applied. Were the blow able to take full effect before the specimen had reached a nearly or quite steady state, it might be expected that the bar would snap off sharply, on the same principle that a candle fired from a fowling-piece penetrates the wooden panel of a door. Probably the specimen breaks owing to excessive tension on the under side. The tension would be proportional to the maximum force exerted by the tup during impact, and as the blow is measured by the loss of momentum, so is its force by the rate of that loss. It therefore follows that in a machine in which the tup is brought to rest from a velocity due to a fixed height the maximum stress on the under side of the specimen will depend upon the time of duration of the blow, and in turn on the distance penetrated by the striking point of the tup. This distance will be made up of the deflection proper of the beam, the elastic deformation at the immediate point of impact, and the plastic deformation at the same point. From these considerations it seems possible to see what happens. A bar with a very high yield point may not appreciably be stressed at, or near, the point of impact beyond its limit of elasticity, and in that case the tup will be brought up sharp. This would result in a very considerable tensile stress being thrown on the under side of the bar; fracture would then be likely to occur. Evidently this effect could arise whether the bar were ductile or not, whether the reduction of area were large or not, and the fact that a steel showed good tensile tests would be no guaranty that it would withstand such shock tests. We are far from pretending that this explains all, or even most, of the difficulties connected with this subject, but it seems to be a reasonable line of argument. It is worthy of note that experiment does rather tend to show that bars which have their yield points low in proportion to their stress limits stand well under shock tests.

It will be admitted generally that the subject is one of importance, and one which deserves very careful consideration. It is to be hoped, however, that any experiments which may be undertaken, either by private individuals or public bodies, will be carried out in an impartial spirit, and not hindered in any way by preconceived notions as to what ought to occur.

ON SMALL PLANTS FOR THE PRODUCTION OF CASTINGS *

By R. M. DAELEN

THE production of ingots in small quantities has occupied the attention of experts to a considerable extent during the last twenty years, because crucible melting is too costly for many purposes, such as steel castings, unless a special quality is required, and because a process is wanted which adapts itself to the ever-changing wants of manufacture in small quantities.

In this respect small Bessemer plants seemed best suited to all conditions, and the author has followed their developments for fifteen years with great attention. So far as this process belongs to modern times — it must be remembered that Sir Henry Bessemer commenced with small converters, and even to-day such converters are at work in Sweden — the late Mons. Ch. Walrand, of Paris, was the pioneer, for he designed and worked the Walrand-Delatte converter towards the end of the eighties, and from this, later on, arose the Robert and also the Tropenas converter. Since then several other variations of the system have been brought out and introduced into practice with varying success. The main feature of the system consists in introducing the air from the side and blowing it on the surface of the bath, as is also done with the so-called Swedish converter, but which has been abandoned for many years with big plants in favor of blowing through the bottom of the converter. There is no really convincing argument for giving preference to blowing small Bessemer converters from the side. On the contrary, it is more difficult to produce the necessary heat in the bath as the combustion of carbon and silicon proceeds more slowly than with blowing from below, and therefore in the former case the pig iron must contain 3 to 4 per cent of silicon, as against 2 to $2\frac{1}{2}$ per cent with the latter, the waste being consequently lower. Also it is impossible to apply the method of blowing from the side to converters of less than $1\frac{1}{2}$ tons capacity, whereas with blowing through the bottom, converters of from 6 cwts. upwards may be used.

In small Bessemer plants in the proper sense only those of Walrand's system should be included, as these work con-

* "The Iron and Coal Trades Review," November 4, 1904.

verters of from 6 cwts. to a ton, whilst those blown from the side require capacities of $1\frac{1}{2}$ to 2 tons, which, with six blows per shift, brings the daily output to between 6 and 10 tons, which is too much for the conditions of most small plants.

So-called "small Bessemer" plants have the advantage, it is true, of easily adapting themselves to small quantities and varying qualities, but according to the latest experience, they can no longer be considered as being economical in their initial as well as in the working costs. The former are high owing to the high-blowing power required, which is about 4 horse-power per 100 pounds of material charged for both blowing the air from the side and from below. With a smaller blowing power as is required for blowing from the side, the time of blowing is longer and the consumption of steam therefore equally high. A basic lining not being suited for small converters, a hematite pig iron high in silicon must be used, which requires a special cupola with a high consumption of coke. Indeed, a complete separation of the iron foundry from the steel foundry becomes necessary, so that there is no advantage to be derived from the existence of an iron foundry.

Assuming that the hematite pig iron costs between 70*s*. to 80*s*. per ton delivered, and adding to this about 50*s*. to 70*s*. working costs, brings the price of molten metal up to 120*s*. to 150*s*., which must be considered as very high, though perhaps the selling price of small castings may permit such a cost if the molding and casting is managed to such perfection that there is no high percentage of defectives.

In this respect, however, the small Bessemer process compares rather unfavorably with the other known melting methods, being to a greater extent dependent on the experience and ability of the engineer or foreman in charge.

An engineer building a plant may say to himself that he will supply a perfect small Bessemer plant and hand it over to the customer after having put it to work, and having produced the daily output as previously settled in quantity and quality, but he cannot guarantee that this state will be lasting, as he has no control in selecting the manager. Wherever the daily output permits it, a both theoretically and practically trained engineer should be put in charge, who not only knows how to make the steel, but also possesses a thorough knowledge of molding and

the further treatment of the finished castings. Unfortunately experts of this kind are rarely at disposal for new plants, and yet the whole success depends on them. Where the plant is too small to pay for an engineer, the responsibility must be almost entirely left with the foreman, and it is perhaps even more difficult to find a suitable foreman than an engineer. Every expert who knows the working of small Bessemer plants will thoroughly agree with these statements. A further difficulty is the treatment of the liquid metal. It is a well-known fact that the quality of steel castings, especially as to density, greatly depends on the temperature of the metal when poured into the molds. In the converter it is very difficult to gauge the temperature, yet the pouring of the metal must be commenced at a certain moment. A great deal of experience is wanted to gauge this temperature by eyesight alone with certainty, and if mistakes were not made in this and other ways, and the figures for defectives were not often high, all steel foundries ought to do splendidly, which, unfortunately, is not at all the case. The difference between the price of the liquid metal and that of the finished casting is extremely high under all circumstances, even with small Bessemer plants. Liquid metal costs, say, £7 10*s*. per ton; steel castings, £15 to £40. The costs of molding, annealing and dressing vary, but they are not so high that a considerable net profit would not be left if the figures for defectives were lower. This, however, almost entirely depends on the experience and ability of the superintendent.

A welcome substitute seemed possible in the small open-hearth furnace on the Siemens regenerative system, which is free from some of the above disadvantages. This furnace was first built by the inventor Martin, of Sireuil, France, some 45 years ago, for a capacity of 2 tons, but it was soon found out that it only worked economically when built to greater capacity. It was only after a long series of years, after a great deal of experience had been gathered with the larger furnaces, that smaller furnaces were again built for steel castings. But even then the lower limit was 2 tons, and larger furnaces, such as 5 tons, were given preference. The open-hearth furnace, however, only showing economical results when continuously worked, the output was frequently too large and it was often necessary to have recourse to making ingots, in the sale of which, however, there is

the competition of big makers, whose costs are about 50 per cent lower. This, consequently, resulted in loss. The main reason for the well-known fact that steel foundries — whether fitted with small or large melting furnaces — do not work satisfactorily, is not only the present scarcity of orders and the low selling price, but above all the absence of proper melting furnaces which can be sufficiently adapted to the varying requirements of the work. In France and Sweden there are already a number of electrically heated melting furnaces working successfully for different purposes. The cost of production of the liquid metal is not too high for steel castings. These furnaces are built for a capacity of 3 tons, and some of them are made of the tilting type, after the style of the Wellman open-hearth furnace, the electric current heating the metal bath from the surface. This system seems unfavorable for small plants in two directions, as both the quantity of metal with each heat and the total production with continuous work become too great. In order to avoid these difficulties, furnaces of the crucible type should be built, with a capacity of from 2 cwts. to 1 ton, and they should be made tilting like a Bessemer converter, and the heat supply must be conducted through the walls of the crucible.

For this purpose the electric arc cannot be applied, but the heat must be produced by electrodes being inserted in the refractory lining. This system has for some time past left the experimental stage, and several plants are at work with success. A suitable shape for the electrodes in actual practice is that of a fine grained composition being filled into the intervals which are left in the refractory walls and which may be refilled after wearing out. This system is built by the Kryptol Gesellschaft, Berlin, and, judging from the results hitherto attained, the field is likely to rapidly expand.

TESTS MADE ON SOLDERS FOR STEEL BRAZING *

From the National Physical Laboratory

THE assistance of the National Physical Laboratory was recently asked on behalf of a skilled workman, Mr. E. Parsons, of Birmingham, who was having difficulty in the brazing of steel joints. Samples of the solder, the steels and the borax were sent to the laboratory for test. Chemical analyses showed that there was nothing abnormal in the composition of the steels, and that the borax was of remarkable purity. The analysis of the solder was as follows:

	Per Cent
Copper	52.53
Zinc	45.46
Lead	1.35
Iron	0.42
	99.76

Five samples of commercial steel-brazing solders were supplied to the laboratory through the kindness of Messrs. Heaton and Dugard, Birmingham, and the following tests were carried out:

1. The brazing qualities were tested, both as regards iron and steel, by Mr. Parsons. In this case heating was performed in an ordinary smith's hearth. Attention was paid to the three leading particulars of temperature, ease of flushing, and tenacity. The last-named quality was tested by breaking the brazed joint with a hammer.

2. Two series of brazed joints of good quality mild steel (0.3 to 0.35 carbon) were made in the factory of the Birmingham Small-Arms Company, Limited, the brazing being done with blow-pipe and gas. One series of joints was tested at the works by breaking them with a hammer; the other series was broken by tension in the testing-machine at the National Physical Laboratory.

3. Complete analyses of the solders were made in the chemical department of the laboratory. The results are tabulated in the two accompanying tables.

* "Engineering," October 28, 1904.

RESULTS OF TESTS

WORK'S TEST	NATIONAL PHYSICAL LABORATORY'S TESTS		SKILLED WORKMAN'S TESTS					
					Tests on Steel‡		Tests on Iron§	
Order of Satisfactoriness as judged by the Hammer Test	Number of Solder	Tons (Avoirdupois) to Produce Fracture per Sq. In. of Brazed Surface	Number of Solder	Behavior on Fusion	Flushing	Tenacity	Flushing	Tenacity
No. 1..	1*	4.26	1	Fairly high melting range (highest of series)	Good	Good	Good	Good
,, 2..	3*	4.19	2	Moderately high melting range	,,	,,	,,	,,
,, 4..	2†	4.13	3		,,	,,	,,	,,
,, 3..	4†	3.94	4	Low melting range	,,	Fair	,,	,,
,, 5..	5†	3.30	5		,,	Bad	,,	,,

* In these two cases fracture took place across the test piece, at the end of the brazed joint.
† In these three cases the brazed joint was stripped from end to end.
‡ The steel was placed inside the fire.
§ Heating was performed on the top of an open fire.

Although five solders have been under examination, the chemical analyses show that the compositions of Nos. 2, 3 and 4 are so similar that it must be admitted that only three types have been tested. This fact is brought into prominence in the table. Solders Nos. 1 and 5 occupy the same positions in each test, the former at the top of the scale, the latter at the bottom of the scale; whereas Nos. 2, 3 and 4 vary their relative positions somewhat.

The National Physical Laboratory tests are the only ones for which a numerical value of the tenacity of each brazed joint can be given, and these do not permit of a distinction being drawn between Nos. 1 and 3.

No. 5 is markedly worse than any of the other joints.

No metal, even in traces, other than those given in the table of chemical tests, was found in the solders.

The tests show that:

1. The higher the copper content is, the better is the solder.
2. Solders 1, 2 and 3 are satisfactory.
3. Solders 4 and 5, and especially the latter, are unsatisfactory, both because they fuse at too low a temperature and do not give a strong joint with steel. There is no obvious reason why solder No. 4 should not be as good as Nos. 2 and 3.

Comparing the chemical composition of the solder quoted at the head of the paper with those of Nos. 1 to 5, it will be seen that the copper content is sufficient to permit of the solder being satisfactory for iron and steel brazing, but that the percentage of lead is considerably higher than that of No. 5, the highest of the series, and that there is a notable amount of iron.

THE NATIONAL PHYSICAL LABORATORY. CHEMICAL TESTS

Number of Solder	Copper	Zinc	Lead	Tin	Total
	Per cent	Per cent	Per cent	Per cent	Per cent
1	63.19	36.31	0.65	Absent	100.15
2	51.83	47.71	0.69	Trace	100.23
3	51.54	47.48	0.84	"	99.86
4	51.39	47.87	0.86	"	100.12
5	49.76	49.16	0.98	"	99.90

The presence of lead in solder will certainly lower the temperatures of the range of fusion, and this fact will tend to make it less satisfactory.

The iron, which has probably been introduced by stirring the molten solder in manufacture with iron rods, and which was present, at any rate partly in the form of dirt, will certainly have a detrimental influence, for it will hinder the solder from flushing completely, and it will prevent the formation of a clean joint.

The influence of lead and iron in solders of this type, as regards their application to steel brazing, seems to be a suitable subject of further research.

The laboratory is indebted to Mr. Parsons for having called their attention to this matter, and to Messrs. Heaton and Dugard, and the Birmingham Small-Arms Company for the assistance they have rendered.

The tests were carried out under Dr. Carpenter's superintendence, in the metallurgical department of his laboratory.

THE PRACTICAL HANDLING OF HIGH-SPEED STEEL *

ITS extreme hardness and its exceeding brittleness are the chief difficulties in using high-speed steel. Finding after a few experiments that it lacked the toughness of ordinary tool steel and that it required an entirely different treatment, many a user has continued to use the old tool steel where a high-speed steel would really, had there been more experience, have demonstrated its superiority in working and in greater economy. Right here is the crux of the situation. The question of brittleness or toughness is almost wholly a question of treatment. A properly treated tool of rapid cutting steel will stand up under any proper condition of work, and will ordinarily do anything that can be reasonably expected of it. But proper treatment is a matter of experience, almost wholly.

A tool dresser may be ever so expert in handling common tool steels, and yet fail utterly with the new steels. The fact is, he cannot depend upon his knowledge of ordinary steels for assistance in working up high-speed tools. He must learn an entirely new set of properties and must be governed by an entirely different set of color values. The fitness of an alloy-steel tool does not depend upon its being too hard for the file. In fact, with some makes the best results are obtained from a tool soft enough to take a good file; with others, again, a similar degree of softness, or even much less, would result in a "gumming up" of reamers, drills, or other tools where there is friction when working, and rapid burning out of the tool. Experience alone will determine just what is most satisfactory for any particular make. We can, however, lay down a few general principles applicable to most of the rapid cutting steels.

Heating the Steel. — The small lathe tool, broken directly from the bar and set in a tool holder, of course needs no further treatment than simply grinding to the required nose. After forging, or brazing to an inexpensive metal, however, it requires careful rehardening; and upon doing this properly and upon the subsequent annealing depends the value of the tool. We find that best results are obtained, particularly in the case of large or closely sized tools, when they are heated packed, and in a

* W.B. in "The Iron Age," October 6, 1904. Abstracted.

closed gas furnace. The tools are placed in a pipe or box, packed with small pieces of coke, and sealed up with fireclay. Holes must be left for the escape of gases, or the sealing will otherwise blow out. According to size the case is heated three to four hours in a furnace previously raised to a white heat, at the end of which time the packing is quickly removed and the tools plunged into the bath. The latter should be very near at hand, so that there is the least possible exposure of the tool to the air after removal from the packing case and the enveloping gases, because such exposure causes oxidation and consequently affects the size, and also the evenness of the tempering.

Hardening. — The quickness with which the tools can be handled, and therefore the accuracy of the hardening, depend largely upon the method of packing; and this, in turn, depends somewhat upon the shape of the tool and its size. They should be so packed as to permit the free circulation of gases, and of the bath oil if they are all plunged simultaneously, as they should be to get even results. Milling cutters and others that can be so placed may be suspended from a bar, each separated from the next by a little space. The rod can then be quickly removed with the tools and plunged into the fish-oil bath. It is important that the precaution of separating the pieces sufficiently to allow the oil to come in contact with the whole surface be not overlooked; otherwise there will certainly be a number of cracked or flawed pieces, the unequal cooling setting up internal strains. Sometimes the crack does not appear until the tool has been some time at work. We had some expensive experience along this line.

The bath should be of fish-oil, placed convenient to the furnace, and, if much hardening is to be done, should be arranged so as to permit keeping the oil uniformly cool. This is accomplished by using a double tank, the oil tank being jacketed by flowing water. Allowing air to bubble up from the bottom also assists in keeping the temperature uniform.

It may be asked, Why not harden the tools in air, as is recommended by some makers? A reason has already been given: that it causes oxidation and therefore affects the size of a tool, and this is to be avoided in the case of accurately sized tools. Aside from this, as good results can be had with air as a hardening agent as with oil.

Drawing Alloy Steels. — High-speed tools hardened as above are quite likely to be too brittle and hard for some uses. Drills, taps and other cutters with small cutting edges are almost sure to be so, with the result that after a little dulling the edge breaks down. This can be avoided by annealing or drawing. But drawing alloy-steel tools is a very different thing from drawing carbon-steel ones. There is an entirely different series of color values that must be used — if, indeed, it is safe to depend upon the eye at all. The safest method is to use an accurate temperature gauge and a systematic record of heats found to be satisfactory for particular jobs. Only in some such way can uniformity be maintained. But where this is not possible of course it is necessary to depend upon the experienced eye. Only experience will give the required skill and judgment for that, so about all that can be said further is that the blue heat sufficient for carbon steel is wholly insufficient for high-speed steel. The heating must be carried along until a greenish tinge, varying somewhat for different classes of work, is reached. The tool is then allowed to cool in air, as usual. If it is found to require further softening and toughening, this may be done by reheating to a faint red just perceptible in the dark. We use a nail keg to get the dark place. It is then cooled as before and will stand up to any reasonable requirement.

The comparatively very high cost of the new steel makes it often questionable if it pays to use it in large tools. In practically all small cutting tools there is no such question. In the case of large reamers and millers the saving, if any, is in many jobs very slight. We no longer attempt to make such tools of high-speed steel. We make the cutters of it, and insert them in properly formed holders made of the cheapest material that will stand up under the work required. The result is that we actually make these large tools (not in all cases, however) cheaper than it was possible to make them of good tool steel. We are, therefore, getting from three to ten times the work we formerly got from such a tool made of carbon steel, at a cost actually less.

THE PROGRESS OF HIGH-SPEED STEEL *

THE manufacturers of high-speed steel expect that the present year will establish a record in the sales of that material, chiefly on account of the greatly increasing demand for it from the United States. Ever since its introduction the consumption of high-speed steel has been a growing one, the rate of increase being accelerated from time to time by the discovery of new purposes to which the material was applicable. Orders for 50 and even 100 tons of tool steel have been received in Sheffield from the United States. For a material which is quoted and sold by the pound these are imposing figures. Whether the output will ever reach that of carbon tool steel is doubtful, if for no other reason than that a pound of the new steel goes as far as five or six of the old. It is no uncommon experience to hear persons in the steel trade, even those who are successful makers of the new material, deplore that high-speed steel was ever discovered, and describe its introduction as a misfortune to Sheffield, owing to the reduction in the bulk of tool steel required, and to the policy of price-cutting adopted by two or three firms, which, it is said, causes high-speed steel to carry less profit than the old kind. This statement is probably true when the waste and trouble which the making of the new steel involves are taken into account. The reduction of bulk is also unfortunate for the rolling-mills which work for hire, as it has lessened the weight of steel sent to them for preparation, with the result that makers who have their own mills are said to have difficulty in keeping their plant adequately supplied with work. The output of carbon crucible tool steel, already comparatively small, is still constantly dwindling. Besides suffering from the competition of high-speed steel as regards the best qualities, it is being hit at the other end by the increasing use of high-grade Siemens-Martin steel, which is now produced from Swedish iron in qualities good enough for the manufacture of files and cutting tools.

Makers of high-speed steel are now obtaining some welcome relief in the reduction of the cost of tungsten, the principal alloy used in the manufacture of their specialty. A few years ago

* "The Ironmonger" (England), January 28, 1905.

tungsten could be bought at 1*s*. 6*d*. per pound, but last year the price rose as high as 4*s*. 3*d*. per pound, and at times it was difficult to obtain supplies owing to the rapid increase in the consumption of the metal. Lately, however, new sources of supply have been discovered, and at present the price has dropped to 3*s*. per pound, and a further decline is believed to be in sight. The new steel is often termed " alloy steel " in recognition of the important part which alloys play in its composition, and the supplier of the alloys has been rapidly forced into a position of great importance in the steel industry. No two makers use the same mixture, and the alloy merchant must, to a great extent, be acquainted with the details of each particular blend. In the old days the melter at a crucible-steel works held in his own breast the secrets of the mixture, his employer being often quite ignorant of its composition, and, consequently, at the mercy of his servant, who then could almost command his own terms. But the partial eclipse of the melter has not altogether freed the manufacturer, for the introduction of high-speed steel has, to a large extent, put the alloy merchant in the place of vantage previously held by the older keeper of the secret.

The new industry of making twist drills from high-speed steel is doing well in Sheffield. All the plants for their manufacture have been fully occupied ever since they were laid down, and the demand has now overtaken the supply. Steady progress is being made in the employment of high-speed steel for making saws for cutting cold metal, although this development is still in the experimental stage. There appears to be a keen demand for reliable saws of this kind at good prices. A considerable quantity of smaller saws are in regular use, and trials are occasionally being made of saws of large diameter for cutting up steel castings and girders. With the latter some remarkable results, it is said, have been achieved. Saws up to 42 inches diameter are being made of high-speed steel and also of a steel of special mixture. The former are difficult to hammer, and as the risk of damage in the process is great, the cost is high. The idea of inserting high-speed teeth in saw plates of mild steel is still occupying attention, several patents having been taken out for methods of carrying it out.

SPECIAL NICKEL-STEEL ALLOYS *

Recent Applications of the Nickel-Steel Alloy of Minimum Expansion in Geodesy and Horology

Comptes Rendus — Nature

WE have repeatedly referred in these columns to the interesting results which have been obtained with various alloys of nickel and iron, and more than three years ago a leading article was published in this magazine, by Professor Guillaume, to whom most of the information is due concerning the subject. We now have an account of the latest results in this important and interesting field of research in a paper by Professor Guillaume published in " Nature " as well as a contribution by M. Mascart in a recent issue of " Comptes Rendus," from both of which some abstracts are made.

The effect of the addition of a small percentage of nickel to steel in increasing the toughness of the product has been known and used by manufacturers for many years, but it was not until the scientific researches of M. Guillaume that the curious properties of the higher alloys were developed. These investigations of M. Guillaume were stimulated by certain observations concerning the physical properties of certain nickel-steel alloys, notably the fact noted by Dr. John Hopkinson, in 1889, that a ferro-nickel containing about 25 per cent of nickel had its density reduced by about 2 per cent after cooling to the temperature of solid carbon dioxide, and also the observations of M. Benoit, in 1895, upon an alloy of iron with 22 per cent of nickel and 2 per cent of chromium, this having a coefficient of expansion half as great again as that required by the law of mixtures.

The most apparent peculiarity of certain nickel-steel alloys was the fact that, although composed of two magnetic elements, some of them were not themselves magnetic except under certain conditions, and further investigation showed a relation between the properties of magnetism and expansion. These relations have been discussed at length by M. Guillaume, both in the article written by him in this MAGAZINE in 1901, and in a more recent paper in the " Revue Générale des Sciences," and his present paper deals more directly with the practical application of cer-

* " Engineering Magazine."

tain of the alloys, notably that containing 36 per cent of nickel and 64 per cent of iron, this being the alloy of minimum expansion. Because of its practical invariability in length under ordinary differences of temperature, this important alloy has been given the name of "invar" by Professor Thury, and under that name it is now generally known.

According to the diagram given by Professor Guillaume, the coefficient of expansion of invar is about 1 micron per meter per degree centigrade, or about one part in one million, but a slight variation in the proportion of either element causes a rapid increase in the value of the coefficient, so that the greatest care is required in the manufacture of the alloy. Thus, the 27 per cent alloy has about the same coefficient of expansion as iron, while a nearly proportionate rise occurs if the percentage is increased beyond the 36 per cent nickel content. When the material is required for particular purposes, price being a secondary consideration, it has been found possible to select samples which have a zero or even a negative expansion, the alloy in the latter case actually becoming shorter for an increase in temperature.

These properties naturally indicated the adaptability of the alloy for the manufacture of standards of length, the troublesome temperature correction being eliminated. Careful experiments, conducted over considerable periods of time, have shown, however, that there is a slow and very slight increase in length with the lapse of time, this increase being about 1/100 of a millimeter in five or six years, at ordinary temperatures, after which the subsequent yearly lengthening does not exceed a fraction of a micron. This action may be enormously accelerated by heating, so that bars may be seasoned in this manner, and their error from this cause almost entirely eliminated, but this fact renders the alloy unsuitable for use in the production of reference standards of the first order.

For working geodetic standards of length, however, invar has shown itself to be admirably adapted, especially in connection with the Jäderin system of base-line measurement with wires operated under constant tension. The old method of base-line measurement, using bars of moderate length, is slow and cumbrous, while the frequent repetition of readings multiplies in corresponding degree the element of observation errors.

Unless the iced bar is employed, the temperature correction becomes an important matter, including all the difficulties of determining the true temperature of the bar, so that the operation is one demanding improvement. The original apparatus of Jäderin involved the use of two wires, one of steel and the other of brass, these being of the length of the standard tapes, usually 24 meters, or sometimes 100 feet, the ends being provided with short graduated scales. The wire, when used in measurement, is supported upon tripods at the ends, and strained taut by a constant weight, and it is possible by its use to measure a base fully ten times as rapidly as with the bars formerly employed. By making the measurement simultaneously with wires of brass and steel the difference could be used as a measure of the mean temperature, from which the proper correction of the length given by the steel wire might be deduced. The application of wires made of invar to this method will readily appear, and trials were so encouraging that it was decided to use a single wire of the nickel-steel alloy for the base measurements in the Spitzbergen survey. An account of this work has already been given in these pages, and it has been shown by comparative measurements of the same base that the error was only 1/500,000, without any temperature correction whatever. Similar experiments in connection with the French equatorial survey in Ecuador have shown that the difference in the measurement of a base with a bimetallic scale and with a wire of invar was 1/3,300,000.

In order further to establish confidence in the reliability of wires of invar for geodetic measurements, a number of experiments have been made by MM. Benoit and Guillaume at the Bureau of Weights and Measures, more than a hundred thousand comparisons having been made during the past four years. In general, it may be stated that the introduction of this method of measurement has enabled base lines to be measured with an accuracy well within the limit of accuracy of the angular measurements, so that the general reliability of a survey may be controlled by the frequent and convenient measurement of base lines.

The communication of M. Mascart to the French Academy relates to the use of invar as a material for the pendulum of an astronomical clock. By the employment of the method of

Lippmann of maintaining the impulses by electro-magnets it was found possible to use simple pendulums, without any compensation, in operation in closed cases under constant pressure, with a variation of two seconds in twenty-four hours. The experiments showed that the opportuinty for error was greater in the mode of suspension than in the effect of temperature changes, the use of invar rendering the gridiron or mercurial compensation unnecessary. The low cost of such pendulums renders them especially applicable for railway service and similar operative work.

Professor Guillaume also calls attention to the application of other nickel steels in horology. Thus the 24 per cent alloy has the property ot changing its modulus of elasticity with an increase in temperature, and this variation may be employed to compensate for the change in the elasticity of the spring of a watch at different temperatures. The use of a nickel-steel alloy in connection with the construction of the compensating balance of a chronometer has also resulted in a material improvement in the rate, this enabling the so-called Dent's error to be almost entirely eliminated. The ability to vary the coefficient of expansion by changing the composition of the alloy has rendered it possible to produce certain special metals of peculiar value. Thus, it has been found necessary to employ platinum wire for all electrical connections which involve the fusion of a wire into glass, because the expansion of platinum is practically equal to that of glass, and there is thus no tendency to crack the glass with any change of temperature. Attempts to use wires of other materials have been unsuccessful, since the glass always cracks around the wire. By using an alloy containing 45 per cent of nickel, a coefficient of expansion identical with that of glass is obtained, and this material, to which the name "platinite" has been given, is already extensively used in connection with the manufacture of incandescent electric lamps.

In concluding his paper, M. Guillaume calls attention to two interesting features:

"All these applications which to-day give new resources to science and new economies, representing large sums, to industry, arise from a peculiar phenomenon of equilibrium in the mutual solution of two isomorphous metals; that is one inter-

esting side of the question. There is another one on which I would insist in concluding; it is that these results have been obtained as a sequel to a long series of delicate measurements in which the thousandth of a millimeter was the ordinary unit, and without which no discovery in this domain would have been possible."

METALLURGY IN 1904 *

IN metallurgical matters the principal changes seem to be mainly in the direction of modifying accessory details in existing processes, and especially in arrangements for the supply of fuel materials and the disposal of finished products, such as are called for by the continual increase in the producing power of furnaces and mills. This, at any rate, seems to have been the impression produced by the most modern installations in the United States upon the European visitors during the late meeting of the Iron and Steel Institute, the most striking developments being in the methods of loading and unloading minerals, the charging of blast furnaces, etc., and these, though admirable, were in most cases designed to meet special wants, and therefore not necessarily applicable in other places. Thus, to mention one example, the enormous stock piles of iron ore necessitated by the intermittent character of the navigation of the Upper Lakes are not required in European works, where supplies arrive continuously throughout the year.

The question of the value of the self-tipping skip as a charging arrangement has been somewhat actively canvassed, especially when combined with the use of the double cup and cone furnace top, on account of the imperfect distribution of the materials of the charge in their descent, and consequent undue wear upon the furnace lining, and slung buckets with a vertical drop have to some extent been substituted for the skips. The single cup and cone, with a rotating distributing funnel, has also been found preferable in some instances. On the Continent automatic wire ropeways working continuously with buckets of somewhat less than one ton in capacity have been advanta-

* "The Engineer," January 6, 1905.

geously adopted in several cases, the same ropeway serving several furnaces instead of requiring a separate arrangement for each one, and the motive power required is considerably reduced as compared with the older forms of hoists.

The most interesting novelty, however, in connection with blast-furnace practice is that announced by Mr. Gayley at the New York meeting, namely, the desiccation of the blast by a preliminary chilling of the air before its admission to the cylinder of the blowing engine. This excited the keenest interest among the visiting members, but as it has been so recently discussed in our columns, it will not be necessary to go into further detail, except to notice that the possibility of the saving has been questioned by some continental authorities on theoretical grounds. The general opinion on that ground, however, seemed to be that it indicates an important improvement in the direction of economy, although the extremely expensive character of the plant would be in the way of its general adoption, which can hardly be looked for until less elaborate arrangements have been devised. The continually increasing demand for high-produce iron ores has brought into prominence the question of the employment of enriched concentrates from ores of low yield, for which purpose some method of compacting the product is necessary, as the amount of finely divided ore that can be used in the furnace is limited. A careful advance in this direction has been made at the Härangs works, in Sweden, where pyritic magnetic ores are improved by grinding and magnetic concentration, followed by a slow calcination in a long horizontal furnace, where the heat is brought up to the softening point of magnetic oxide. The product, besides being nearly completely desulphurized, is sufficiently compact and porous to be readily reduced in the blast furnace. The method was described by Prof. Henry Louis in May last, and it has been arranged to adopt it in the large enterprise of the Dunderland Iron Ore Company, in Norway, which expected to become a producer in the course of the year. Other methods depending upon the use of water gas and a siliceous method of cementing by the addition of blast-furnace slag and the action of steam at high temperature are promised, but details as to these are not as yet forthcoming.

The use of the electric furnace in the production of iron

and steel has been the subject of a useful inquiry by a commission appointed by the Government of Canada, who investigated the working of the different systems in the early part of last year. These include the Kjellin process at Gysinge, in Sweden, that of Héroult, at La Praz, in Savoy, and that of Keller, at Livet. From the metallurgical part of the report, which is due to Mr. F. W. Harbord, it appears that the best results have been obtained in the production of the finer qualities of steel, which can be made at a lower cost than in crucibles by the ordinary method of melting. Pig iron made by electricity at a cost of 40*s*. per electrical horse-power per annum would only be on an equality with coke furnaces when the price of the fuel exceeded 28*s*. per ton.

The manufacture of quick-cutting tool steel by the addition of hardening metals to carbon steel, which has now become a matter of general practice, formed the subject of an important communication to the Iron and Steel Institute in America, by Mr. Gledhill, which brought out much interesting detail in the discussion by American members, the publication of which may be shortly expected.

ABSTRACTS *

(*From recent articles of interest to the Iron and Steel Metallurgist*)

EUROPEAN Gas Engine Practice. A. H. Allen. "The Engineer" (Chicago), January 1, 1905. 3,000 w., illustrated. — The rapid development of the modern large power gas engine is one of the most striking engineering phenomena of recent years; even so lately as 1898 an engine of 200 horse-power was looked upon as exceptionally large, and four years ago the largest engine in existence was of 600 horse-power, whereas nowadays engines of several thousand horse-power are not uncommon. The fundamental cause of this sudden growth was simply and solely the discovery that "poor gas," such as that given off from blast furnaces, could be utilized directly in the gas engine — a discovery made in the first instance by B. H. Thwaite, though the credit of applying it on a large scale belongs to Messrs. John Cockerill, of Seraing, Belgium, to whom more than to any other firm is due the introduction of large units. Messrs. Cockerill, however, were somewhat too optimistic in the earliest stages, for they declared that the waste gases could be utilized in their raw and dirty state as they came from the furnaces; it is now recognized that, save in exceptional cases, the gases must be properly cleaned before use, a fact appreciated by Mr. Thwaite from the first; he, indeed, designed a complete system of cleaning apparatus ten years ago, and many installations have been equipped therewith and have given satisfactory results.

While Messrs. Cockerill commenced with single-cylinder

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* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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four-stroke cycle engines, they soon added two-cylinder tandem, and double tandem or four-cylinder engines to their designs, the latter giving a high degree of cyclic regularity; later still, recognizing the great weight and cost entailed by the use of single-acting cylinders, they have adopted the double-acting type, giving, with two cylinders, one impulse per stroke. The author describes other gas engines such as the Koerting, the Oechelhaeuser, the Premier, the Simplex (Cockerill), etc. **No. 301. B.**

The Development of the Gas Engine. Albert Stritmatter. "The Engineer" (Chicago), January 1, 1905. 1,200 w. — The article describes the evolution of the gas engine. Owing to the difficulties in construction, it has only been very recently that double-acting engines have been built in this country, although some have been in operation in Germany and other European countries for a longer time. These large engines are usually designed to operate on blast-furnace gas or some kind of producer gas. One of the largest gas-power installations in this country is at Buffalo, where eventually 40,000 horse-power in 2,000-horse-power units of two-cycle engines will be installed. At Madrid, Spain, is an installation of 2,000 horse-power four-stroke cycle engines, aggregating 12,000 horse-power.

Blast-furnace gas, with which these large engines are used, is of a low calorific value, and a higher compression is possible than with natural gas. Various estimates have been made as to the eventual relation of the gas engine to the blast furnace. Edward A. Uehling has figured that for every ton of pig iron produced per hour in a blast furnace, there is sufficient gas generated to produce nearly 850 available horse-power, in addition to the power required for the furnace. Other metallurgists have made similar estimates, and some have gone so far as to prophesy that the blast furnace of the future will be primarily a gas producer for gas engines, and the pig iron will be a by-product. **No. 302. B.**

Experience with Large Gas Engines. "The Iron Age," January 19, 1905. 2,500 w., illustrated. Abstract of an address by Herr Strack reproduced in "Stahl und Eisen." — "The German writer thinks that the battle for supremacy in large gas engines is between the double-acting four-cycle engines, the Koerting

and the Oechelhaeuser types. Further, that victory will not necessarily rest with the engine using the least gas, but with that which offers the greatest security in operation. He is also of the opinion that the gas engine is not suitable for rolling mills, as it needs too many repairs, too much room and too much attention. Blowing engines will be driven direct, and other gas engines will be used for generating electricity, which in turn will drive rolling trains, cranes, etc. **No. 303. B.**

Current Practice in Combustion Engines. "The Engineer" (Chicago), January 1, 1905. 30,000 w., numerous illustrations. — A fully illustrated description of the Nurnberg Gas Engine as built by the Allis-Chalmers Co., Milwaukee, Wis., which has been designed especially for the use of blast-furnace gas. Other gas engines are also fully described. **No. 304. B.**

The Lackawanna Slabbing Mill. "The Iron Age," January 5, 1905. 1,400 w., illustrated. — An illustrated description of the slabbing mill of the Lackawanna Steel Company, at Buffalo, N. Y. In capacity, weight and massiveness of construction, it is said to surpass anything yet undertaken in the line of rolling-mill machinery. The total weight of the mill, tables and engine, is 4,200,000 pounds, or 2,100 net tons. Not only is massiveness of construction in mills of this type becoming appreciated, but the advantages of the slabbing mill as a type and as a factor in rolling-mill economics are becoming recognized and it is predicted that this type of mill will largely supplant the orthodox blooming mill.

The slabbing mill can reduce the width of an ingot, while it is being reduced in thickness, thus making it feasible to produce, from a few standard sizes of ingots, slabs of any desired width and thickness within reasonable limits, thereby simplifying the work in the converting department and obviating the necessity for carrying a large assortment of various shapes and sizes of ingot molds. It can also, by substituting suitable horizontal rolls and retracting the vertical rolls to their extreme outer position, be used as an ordinary blooming mill for the production of blooms or billets. Furthermore, by using plain horizontal chilled rolls in conjunction with the vertical rolls, universal mill plates can be rolled, and, by retracting the vertical rolls, the mill

can be used as a reversing plate mill. It can therefore be readily seen that this type of mill is a very useful one, and particularly so where the product of the finishing mills covers a wide range of sections for which suitable sizes of billets, blooms or slabs must be provided, or for mills doing a jobbing business. **No. 305. B.**

The Manufacture of Chain. L. B. Powell. "The Iron Age," January 5, 1905. 4,000 w., illustrated. — A simple description of the various operations connected with the manufacture of chains. The author writes that "to obviate the 'tiring' of a chain, as this is known, it should be made a point to anneal the chain at least once a year, which is easily done by subjecting the entire chain to a uniform heat in a furnace, care being taken that the chain should never be heated to more than a red heat. After remaining in the furnace at a red heat at least four hours, the chain should be permitted to cool gradually in a bath of sand. When the chain has cooled thoroughly, it should be carefully inspected for links that show signs of visible wear, and these links should be cut out and replaced with new links. The chain should now be given a good oil bath and is then ready for use." **No. 306. B.**

Blast Furnace Vertical Blowing Engines. "Engineering," January 6, 1905. 1,800 w., illustrated. — As has been pointed out time and again in "Engineering," there is a continuous effort on the part of iron-masters to increase the producing capacity of blast furnaces, and less heed is paid now to the duration of the furnace in point of time, and more to the production for each lining. This has necessitated the providing of modern blowing engines working at higher speeds and at increased blast pressures, with a preference, of course, for such designs as give economical results as regards steam consumption. The North Eastern Steel Company at Middlebrough, as the result of experience with two engines, by Messrs. Davy Brothers, Limited, of Park Iron Works, Sheffield, have recently had installed a similar engine at their Acklam Works, embodying, however, several interesting departures in detail. This engine is described and illustrated in the article. **No. 307. B.**

Melting with the Air Furnace. Dr. R. Moldenke. "American Machinist," January 5, 1905. 2,200 w., illustrated. — A description of various designs of air furnaces, with a critical review of their relative merits. The author concludes as follows: " For the benefit of the machinery trade it is to be hoped that the air furnace will come into more general use, as nothing is more annoying than to have a casting break after much machining has been done on it. Air-furnace iron promises much in the way of relief herein." **No. 308. A.**

The Manufacture of Cast-Iron Car Wheels. " The Iron Age," January 5, 1905. 4,000 w., illustrated. — A description of the operations at the new plant of the Pennsylvania Railroad Company at South Altoona, Pa. It is said to be the largest and most modern plant for the manufacture of cast-iron wheels, and to have a capacity of 900 wheels per day. **No. 309. B.**

Mechanical Handling in the Manufacture of Iron and Steel. James N. Hatch. " Engineering Magazine," January, 1905. 6,000 w., illustrated. — An exhaustive description of labor-saving appliances in the manufacture of iron and steel as applied to the mining of the ore, the transportation to the furnaces and the conversion of the ore into steel. **No. 310. C.**

The Garrett Reheating Furnace. J. S. Trinham. " The Iron and Coal Trades Review," December 30, 1904. 3,500 w., illustrated. — A paper read before the Staffordshire Iron and Steel Institute, December 17, 1904. The author describes the Garrett Reheating Furnace, recommending its adoption to the directors of the steel works with which he is connected. **No. 311. A.**

Steel for the Manufacture of Artillery. Lieutenant-Colonel Cubillo. " Page's Weekly," January 6, 13, 20, 27, February 3 and 10. 9,000 w., illustrated. — The article is chiefly intended to show the present state of the iron and steel industry as applied to the manufacture of materials for cannon in the United States. **No. 312. Each A.**

The Pyrometer in Blast-Furnace Practice. S. H. Stupakoff. " The Iron Trade Review," January 5, 1905. Paper read before

the Pittsburg Foundrymen's Association. 2,500 w., illustrated. — A description of the application of the Le Chatelier thermo-electric pyrometer to blast-furnace practice. **No. 313. A.**

Aluminothermics. "The Foundry," February, 1905. 2,000 w., illustrated. — A description of the application of aluminothermics with special reference to the mending of cast-iron castings. **No. 314. A.**

Rolls for Uneven Angles. William Hirst. "The Iron Age," January 12 and 19, 1905. 4,500 w., illustrated. **No. 315. Each B.**

The Hughes Hydraulic Billet Press. "The Iron Age," January 19, 1905. 600 w., illustrated. — Description of a cheap process for manufacturing steel billets in small quantities. **No. 316. B.**

Stock Distribution in the Blast Furnace. Jos. E. Raysor and John J. Porter. "The Iron Age," January 12, 1905. 1,500 w., illustrated. **No. 317. B.**

Rails for Lines with Fast Trains. Dr. P. H. Dudley. "The Railroad Gazette," January 6, 13 and 20. 5,000 w. Abstract of a report to be presented to the International Railway Congress, May, 1905. **No. 318. Each B.**

Suction Gas Producers. B. A. Sinn. "Power," December, 1904. 3,500 w., illustrated. — An illustrated description of suction gas producers including the Bernier, Dawson, Baltimore, Benz, Pintsch and Koerting types. **No. 319. B.**

American Suction Gas Producer. "The Engineer" (Chicago), January 1, 1905. 2,500 w., illustrated. **No. 320. B.**

Direct Casting from the Blast Furnace. "The Iron Age," January 12, 1905. 2,000 w., illustrated. — A description of the methods of production of cast-iron tunnel segments as pursued at the works of Thomas Butlin & Co., Wellingborough, England. **No. 321. B.**

Forging Machinery. J. H. Baker. "Proceedings of Engineers Society of Western Pennsylvania." 3,000 w. — An interesting description of the evolution of forging machinery. **No. 322. C.**

The Mesabi Iron Ore Range. Dwight E. Woodbridge. "Engineering and Mining Journal," January 12, 19 and 26, 1905. 12,000 w., illustrated. **No. 323. Each A.**

Physical Characteristics of Certain Bronzes for Steam Uses. Strickland L. Kneass. "Journal of the Franklin Institute," January, 1905. 3,000 w. **No. 324. C.**

The Metallography of Steel. Percy Longmuir. "Technics," December, 1904, and January, 1905. 6,000 w., 19 photomicrographs. — The author describes and illustrates the microstructure of steel. **No. 325. Each B.**

Rolled-Steel Car Wheels. Samuel M. Vauclain. "Journal of the Franklin Institute," February, 1905. 1,500 w., illustrated. —An illustrated description of the manufacture of rolled-steel car wheels by the Standard Steel Company, at Burnham, Pa. **No. 326. A.**

The Swindell Water-Seal Gas Producer. "The Iron Age," February 23, 1905. 1,000 w., illustrated. — An illustrated description of a gas producer patented by James H. Swindell and manufactured by the American Furnace and Machine Company, Pittsburg, Pa. **No. 327. A.**

METALLURGICAL NOTES AND COMMENTS

Hermann Wedding We reproduce as a frontispiece to the present issue of the *Iron and Steel Magazine*, a recent photograph of Dr. Hermann Wedding, the veteran professor, writer and metallurgist. Dr. Wedding was born in Berlin, March 9, 1834. He attended the classical gymnasium of "Graue Kloister" in Berlin, from which he graduated in 1853. After leaving this school he served a two years' apprenticeship at some of the government smelting works in Upper Silesia, at the conclusion of which he studied at the University of Berlin and at the Mining Academy at Freiberg, receiving his doctor's degree in 1858. Two years later he passed his examination of "Bergreferendarius" in Breslau, this being the first examination required to enter the service of the government. In 1862, Dr. Wedding was appointed German commissioner to collect and arrange mining and metallurgical products for the International Exhibition at London. It was the first time that such an exhibit was attempted and the undertaking was highly successful. The following year Dr. Wedding took his second government examination, that of "Bergassessor" and was then appointed instructor in metallurgy at the Bergakademie of Berlin. His promotion was afterwards rapid, being appointed in succession, Professor "Bergrat" and "Geheimer Bergrat" and receiving orders from Prussia, Sweden, Russia and Austria, as well as many gold, silver and bronze medals, among which should be noted the Bessemer Gold Medal of the Iron and Steel Institute and the Gold Medal of the German Association for the Promotion of Technical Industry.

Dr. Wedding has contributed generously to the literature of the metallurgy of iron and steel. Among his most important writings the following should be especially mentioned: "Handbuch der Eisenhüttenkunde," a new edition of which has just been published, "Grundzüge der Eisenhüttenkunde," now in its fifth edition, the "Bessemer Basic Process," etc.

Dr. Wedding is an honorary member of the Verein Deutscher Eisenhuttenleute, the Iron and Steel Institute, the American Institute of Mining Engineers and of many other technical societies.

The Combined Pneumatic and Open-Hearth Process

About a year ago there were installed at Ensley, Ala., as an adjunct to the regular basic open-hearth steel plant, a standard 15-ton Bessemer converter and an acid-lined rolling primary furnace of 250 tons capacity. The plant, which is owned by the Alabama Steel and Shipbuilding Company and operated under lease by the Tennessee Coal, Iron and Railroad Company, consisted of ten 50-ton basic-lined, open-hearth furnaces, nine of which were rolling and one stationary. The stationary furnace is having a movable top provided, to permit the charging of very large pieces such as rolls, skulls, etc. As we understand it, the situation was that scrap, which in the North is used to shorten the time of making a heat, was not available in large quantities, while it was hoped with the use of these adjuncts to surpass, with the use of pig iron alone, the records of Northern furnaces which use as much as half scrap. We have no exact data as to the cost of operation under the combined process, but it is a matter of general knowledge that for months this plant has been making basic open-hearth steel rails which meet all the requirements, and that the scrap thus arising, as crop ends, etc., has been sold in the North as low phosphorous material, thus commanding such a premium as to pay the freight — which is $4.85 to Pittsburg — and still net a good price f.o.b. works. The primary rolling furnace accomplishes all that the mixers do at other works, and in addition does some work, how much we do not know, in decarburizing and desiliconizing the metal. The Bessemer vessel which works in conjunction with it can, of course, eliminate all the excess carbon and silicon, and, altogether, the practice represents a very important departure from practice elsewhere, in the United States at least. As other means for reducing the amount of scrap needed in rapid working have not met with the general adoption which was expected in some quarters, some system like that used at Ensley may, in the future, become very important. It is obvious that with the basic open-hearth process growing

much more rapidly than the Bessemer, even should the latter continue to grow at all, sufficient scrap cannot indefinitely be found for the practice of the process in the ordinary way. The supply cannot increase more rapidly than the total production of steel increases, while the production of the basic open-hearth furnace increases more rapidly than total steel production. Besides, the tendency in recent years has been for the lighter finished steel products to increase more rapidly than the heavy lines, which are good scrap producers. Wire production, for instance, has increased much more rapidly than rail production.

Basic Pig-Iron Production Increased

The statistics of pig-iron production in the United States reached us just as our last issue was going to press, and we could do no more than incorporate the total in our table of the world's pig-iron production. The full statistics are now given elsewhere in this issue. The decrease from the figures of the two previous years was fully expected; in fact, until nearly the close of the year a still greater decrease was expected than that now shown, —1,512,219 tons or 8.4 per cent from 1903.

The change in production by grades is partially shown in the following table:

CLASSIFIED PRODUCTION OF PIG IRON, TONS OF 2,240 POUNDS

	1901	1902	1903	1904
Standard Bessemer and low phosphorus	9,596,793	10,393,168	9,989,908	9,098,659
Basic with mineral fuel	1,448,850	2,038,590	2,040,726	2,483,104
Charcoal	383,441	390,169	505,684	337,529
All other	4,449,270	4,999,380	5,472,934	4,577,741
Totals	15,878,354	17,821,307	18,009,252	16,497,033

The decrease in standard Bessemer and low phosphorus is in keeping with the decrease in the total. Low phosphorus is a minor grade, being an iron not over .035 per cent in either phosphorus or sulphur, and the total tonnage is not large. Grades not separately stated in our table above also showed a decrease substantially uniform with the total, while basic pig stands alone in having shown an increase of more than 440,000 tons from either 1902 or 1903. As the statistics of basic open-hearth steel production for the year are not yet available, it is impossi-

ble to determine exactly why this increased production was called for. It may have been because the production of basic open-hearth steel was increased, or it may be because a lesser quantity of scrap was available, requiring a greater percentage of pig iron. Whichever may prove to have been the case — and it is probable that both causes were at work — substantial testimony is offered to the vitality of the basic open-hearth steel process. That it will "go to the funeral of the Bessemer process" as presaged years ago is not yet something that can be definitely stated, yet it certainly is showing greater vitality.

The only states of consequence which increased their pig-iron production in 1904, as compared with 1903, were New York, New Jersey and West Virginia. The increase in New York was due to the starting of furnaces at Buffalo by a merchant interest and by the Lackawanna Steel Company, this representing a further movement towards the manufacture of pig iron on the lake front to avoid the rail haul on iron ore at the lower end of the lakes. The increase in New Jersey was due largely to the erection of an additional modern furnace. The rated capacity of all the furnaces in the state is about double the production in 1904. The increase in West Virginia was due to the completion of a new furnace, which was blown in during 1903, and the rebuilding of an old furnace.

Altogether it may be said that the statistics of 1904 do not show any important movement in the geographical centers of pig-iron production. For many years there has been a movement towards those districts in which Lake Superior ores are most available, but this movement stands out more prominently in years which show an increase in production.

American Pig-Iron Productive Capacity

Estimates of the pig-iron productive capacity of the United States are dangerous. Not only are new furnaces constantly being built and old furnaces abandoned, but there is always a question whether a furnace is abandoned or not. A boom in prices may make active a furnace which otherwise would never again be operated. American blast furnace managers do not always reline furnaces just when the physical condition would require relining. Frequently an opportunity of slack demand is grasped because it is better to lose a little further use of the lining than to face the

necessity of inactivity at some nearby time when the product will be badly needed. Sometimes a high point in demand is reached shortly after a period of dullness, so that at such a time the full capacity of the furnaces is brought out. At other times, a high point in demand is reached after a long period of moderately heavy pressure, and at such a time many furnaces may be in enforced idleness. As far back as June 1, 1904, a summary by the American Iron and Steel Association showed the capacity of the then completed furnaces at 28,114,000 tons, but from this total would have to be deducted the furnaces which could not be cut out of the list, but yet were practically abandoned, as well as that varying proportion of furnaces which must be out for relining and other repairs.

Despite the uncertainties of the case, an estimate at this time should prove interesting. It must be premised that the trade is now in one of the conditions noted above — a period of heavy demand has very quickly followed a period of inactivity, during which an opportunity was afforded for repairs and relining. The estimate will, accordingly, show a capacity which might not be attained under other conditions.

The blast-furnace report of the "Iron Age" showed that on February 1 pig iron was being produced by the coke and anthracite furnaces at the rate of 21,000,000 gross tons annually. The charcoal furnaces are running very slack now, but in 1903 they produced a trifle over 500,000 tons, and could do so again. By a careful study of the whole situation, comparing the rate of production of different districts with the best they have ever done, and counting furnaces which are now idle, but which it is well known can be blown in, there is found to be about 2,000,000 tons annually of idle capacity. This arises largely from the coal strike in the South, and this district is merely given credit for being able to do again what it has done in former times. Then there are, in addition, as reported by the American Iron and Steel Association, as of January 1, 1905, new furnaces being built with a capacity of 1,055,000 gross tons annually. Summarizing, there is presented the following:

ANNUAL CAPACITY GROSS TONS

Coke and anthracite furnaces operating February 1	21,000,000
Possible charcoal pig production	500,000
Idle capacity	2,000,000
Actual present possible capacity	23,500,000
Furnaces building	1,000,000
Total capacity in sight	24,500,000

In the above estimate no furnaces are included except such as are either actually operating, or it is well known can operate, and are certain to be blown in if market prices remain as they are now. On the other hand, if these additional furnaces are not promptly blown in, some of those now operating may have to blow out for relining and other repairs, so that it is possible the aggregate may not be reached. It cannot be, unless promptly, but a productive rate of say 22,500,000 tons could probably be maintained without difficulty to the end of this year, without aid from the new furnaces being built.

In no calendar year has the United States made more than 18,009,252 gross tons, which it did in 1903. In no consecutive twelve months has it made more than 19,100,000 gross tons, which it did, approximately, in the twelve months ended September 30, 1903.

Tonnage of "Bessemer" Railroad

The Pittsburg, Bessemer & Lake Erie Railroad, now operated as the Bessemer & Lake Erie Railroad Company, was established by the Carnegie Steel Company eight or nine years ago to carry iron ore from Conneaut Harbor, on Lake Erie, to Carnegie blast furnaces at Pittsburg, and avoid what were regarded as the excessive freight charges of the trunk-line roads. The ore is carried on a twenty-year contract with the Carnegie Steel Company at a rate of 3½ mills per ton per mile, making a rate of a trifle over 50 cents for the haul from Conneaut Harbor to North Bessemer, where connection is made with the Union Railroad, the terminal road of the steel company. The actual average cost, for a calendar year, of carrying all freight, has shown a minimum of 1.87 mills per net ton per mile, probably a lower average than shown by any other road. Ore is carried for the Edgar Thomson, Duquesne and Carrie blast furnaces.

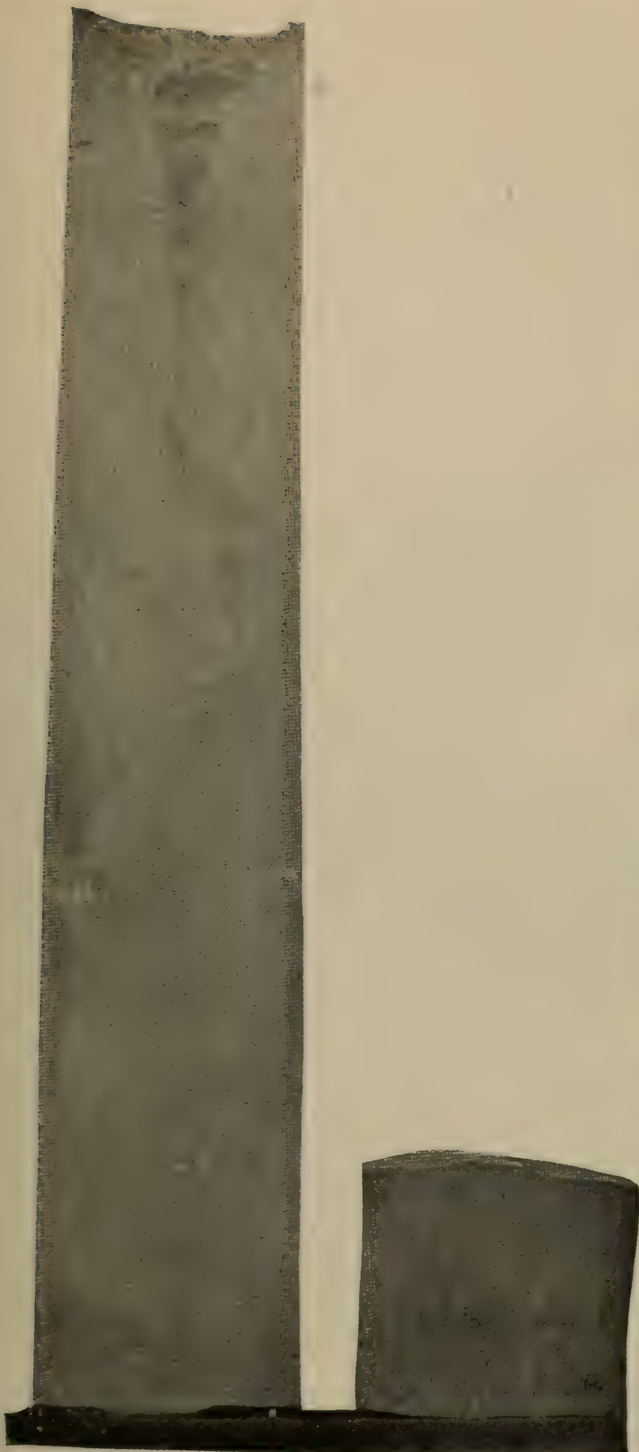
Connections may later be made with other blast furnaces now controlled by the company. The chief problem was to find a return haul for the road, which has been largely accomplished. The following summary has just been prepared. The ore constitutes nearly the entire south-bound tonnage, less than half a million tons of the "other freight" being south bound, the balance being chiefly north-bound coal for the lake trade.

FREIGHT TONNAGE OF "BESSEMER" ROAD, CALENDAR YEARS

	Iron Ore		Other Freight	Total
	Gross tons	Net tons	Net tons	Net tons
1897........	446,810	500,428	650,928	1,151,356
1898........	1,477,768	1,655,101	812,273	2,467,374
1899........	2,176,525	2,437,708	1,054,455	3,492,163
1900........	2,396,474	2,684,051	1,496,340	4,180,391
1901........	3,233,962	3,622,038	1,803,316	5,425,354
1902........	4,183,868	4,685,933	1,993,435	6,679,368
1903........	3,909,982	4,379,180	2,507,317	6,886,497
1904........	4,087,675	4,578,196	2,629,233	7,207,429

Forged and Rolled Steel Wheels. — The Standard Steel Works have issued some attractive and instructive pamphlets descriptive of their manufacture of forged and rolled steel wheels.

The whole wheel is forged as thoroughly as a tire bloom and subsequently rolled to the required form and size, thus so increasing the strength of the hub and web that a much lighter design is permissible, reducing largely the weight in comparison with steel tired wheels. The steel used is made from the acid open-hearth, of composition exactly similar to that used for tires of medium grade of hardness, *i. e.*, from 0.60 to 0.65 per cent carbon. Its method of manufacture, however, appears to increase its density and should give better wear than tires of same chemical composition. The result is a wheel embodying lightness, strength and durability, — three important requisites. These wheels are especially adapted for use under heavy freight cars, express cars, fast freight, etc., and ultimately, if their behavior in service verifies the manufacturers' prediction, they will replace the built-up wheels. They are of especial interest to the managers of electric traction lines, the present heavy equipment and fast running in suburban service demanding a better quality of wheels than those ordinarily used. They can be economically applied to this service.



FIGS. 1 AND 2

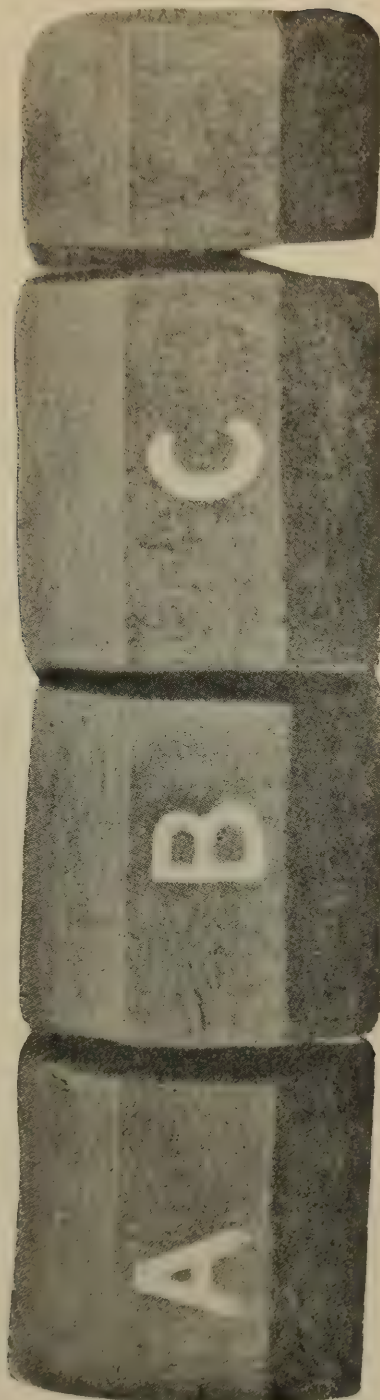


FIG. 3

The billets from which the wheels are made are cut from long ingots, bottom-poured, in groups of molds. The top of the ingot which contains the piping and segregation is discarded, nothing being used for the wheels except billets cut from the solid part of the ingot, thus insuring perfectly solid, homogeneous wheels free from defects which are unavoidable in all wheels made from castings or cast blanks. A graphic illustration of a long ingot is shown in Figs. 1 and 2, Fig. 1 being a photograph of an etched section of the ingot showing plainly the imperfections at the top or the discarded portion, while Fig. 2 shows an etched

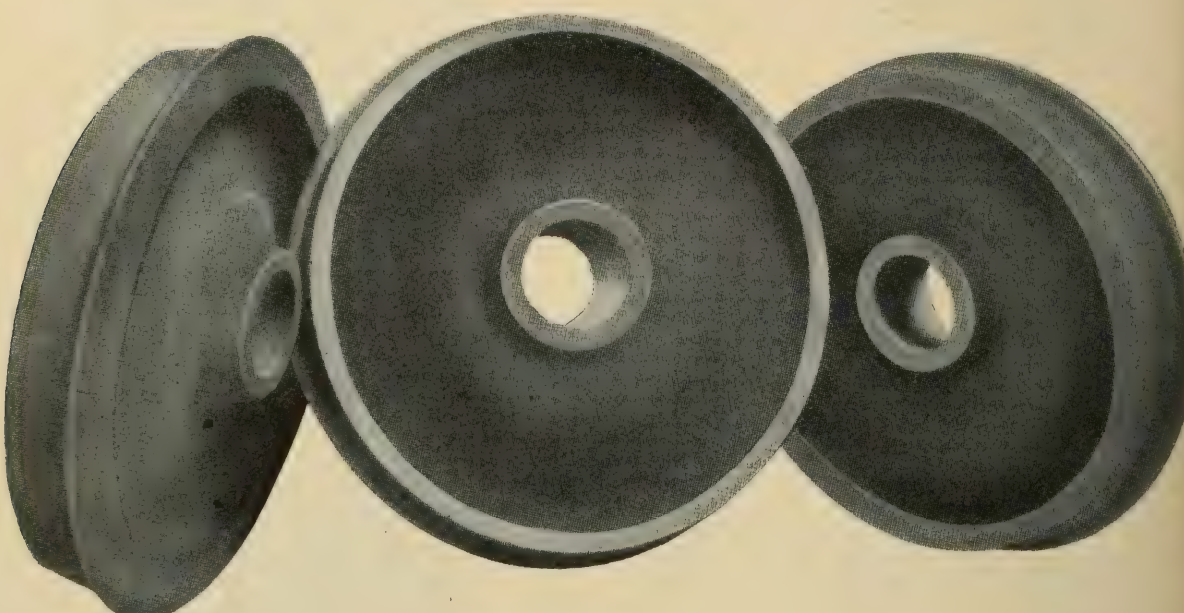


FIG. 4

section of a billet cut from the long ingot, showing the freedom from casting defects.

In Fig. 3 is shown a photograph of the ingot as cut, the lettered portion being used, the unlettered (top) rejected.

After casting, the ingots remain in a perpendicular position until thoroughly set, the molds are then stripped and the ingots piled for future use.

The ingots are heated and cut into billets under a ten-ton hammer, being charged automatically into a long-necked heating furnace and drawn from the furnace and handled on the anvil by an electric manipulator. From four to six billets are cut from each ingot. The billets are then forged under a 5,000-ton

hydraulic press into blanks of suitable shape and then rolled into wheels. The curve in the webs being subsequently shaped in a 500-ton hydraulic press. After careful cooling the wheels are bored and machined, *i. e.*, hubs faced and rims trued to exact diameters.

The examination of many of these wheels — chemically, physically and microscopically — and of numerous etched sections show that the steel is homogeneous, and that work done on the billets by the 5,000-ton press and rolling mill produces material of remarkable density and solidity. In Fig. 4 are shown some finished wheels.

A New Development in Cowper Hot Blast Stoves. — The illustrations herewith show a new arrangement of a Cowper stove fitted with internal valves, which is described by the inventors and patentees, Messrs. E. J. W. Richards and Thos. Lewis, of Glengarnock Iron and Steel Works, as a method of, and means for, cleaning and keeping clear the checkerwork, and for regulating the heat, blast and draught of Cowper stoves. Blast-furnace managers will readily acknowledge that considerable difficulty is experienced in keeping Cowper stoves clean, and they must often have felt that some method of regulating the blast and temperature was much needed.

It is, of course, well known that where there is much dust, carried over by the furnace gases to the stoves, this dust adheres to the checkerwork in a gradually increasing thickness, especially towards the top, and so reduces the area, sometimes, in fact, choking up some of the flues altogether, in consequence of which the heating capacity is daily becoming less, until the stove in time becomes useless. The present method of cleaning a stove by firing a gun or by blowing it through with the blast is quite ineffective, as may easily be seen if the stove is examined after such a cleaning, when it will be found that only a limited area, not usually more than one sixth, around the outside edge has been cleaned.

The only perfect way of cleaning at present in use is by laying off the stove, allowing it to cool, and cleaning it by hand labor, which is an expensive method, besides which the use of the stove is lost during the cooling and cleaning, and also during the time the dust is collecting, the stove, as pointed out above, is becoming gradually less efficient. To prevent this gradual loss

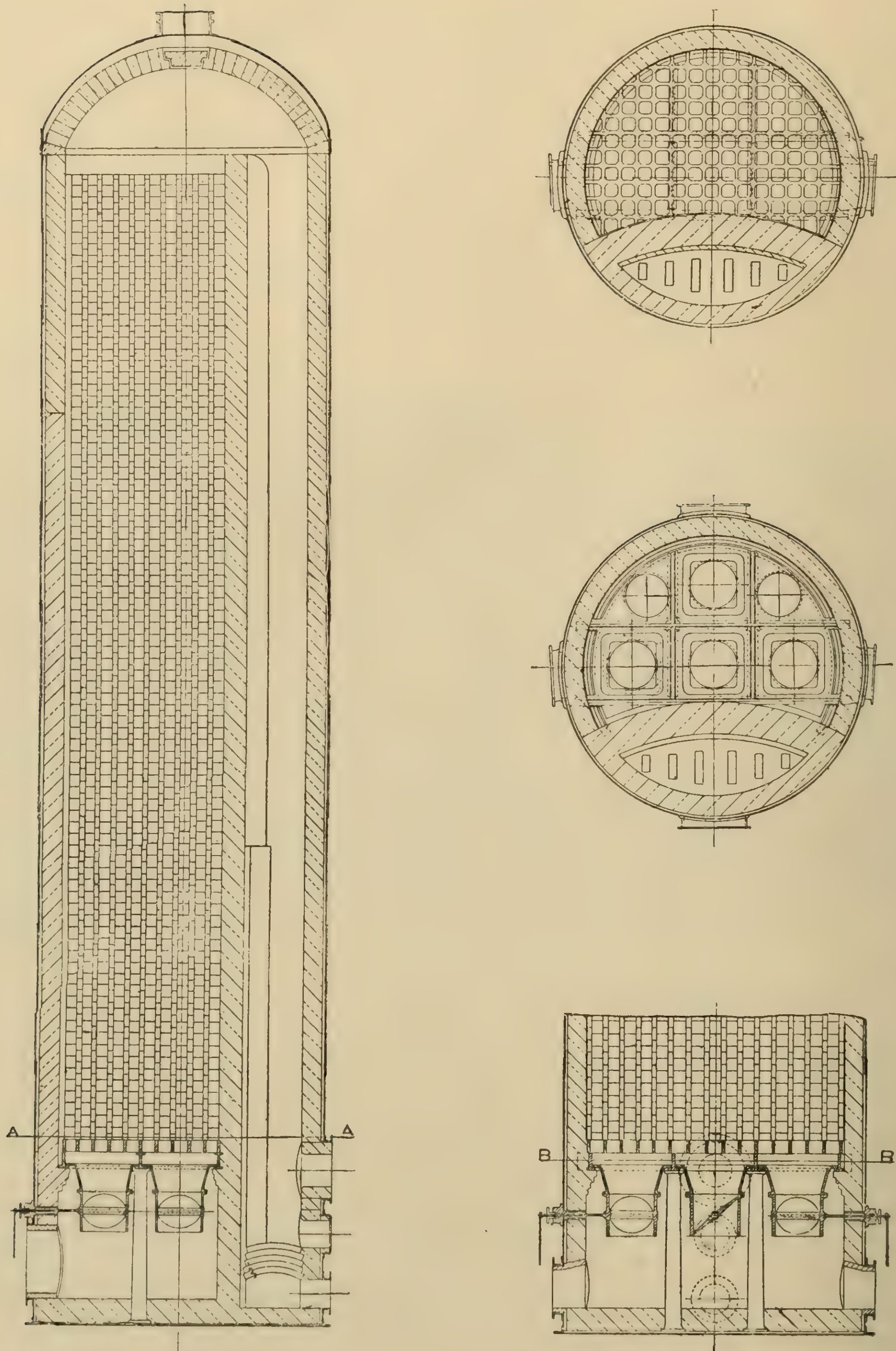


FIG. 1. Longitudinal Section through Cowper Hot Blast Stove.
FIG. 2. Cross Section through AA, Fig. 1.
FIG. 3. Cross Section through BB, Fig. 4.
FIG. 4. Vertical Section of Fig. 3.

of area through the accumulation of dust, and to clean the stove cheaply and efficiently is one of the objects aimed at in Messrs. Richards and Lewis's valve arrangement.

As will be seen from the drawings, the checkerwork is divided into six shafts by means of the internal valves at the bottom, and thus the blast can be directed through any one section at will. To clean the stove, then, it is only necessary to close all the auxiliary valves and fill the portion below the valves with blast; then each valve in succession is rapidly opened and closed, when the blast, confined to a portion of the whole area, and having thus a greater pressure than if the whole stove were open, removes all dust, which can either be blown out through a valve on the dome or down through the gas valve as commonly done at present, or into a main dust collecting tube. The frequency and ease with which the stove can be blown through will insure that the dust will never be left lying long enough on the checkers to become fused on, which is a constant source of trouble in stoves at present.

Even at works using a clean gas in their stoves, such as a plant with coal fuel furnaces with ammonia recovery, or in a coke fuel furnace with gas cleaning plant, this valve arrangement is still claimed to be advantageous, for by means of it the draught and heating can be regulated at will.

In the ordinary Cowper stove, even when perfectly clean, the area of the checkerwork is so much larger than the chimney valve area that the tendency is for most of the products of combustion to pass through only a portion of the stove, and not distribute themselves over the whole area. In this way a great part of the value of the stove is lost. With the auxiliary valve arrangement, however, it is possible so to direct the gases as to heat the entire checkerwork evenly. Thus the stove can be started with three of the valves open, and as soon as the first portion is judged to be sufficiently heated, the other three valves would be opened and the first three closed.

It will also be a well-known fact to furnace managers (more especially in those plants where each furnace is isolated) that there often arise conditions when it would be a decided advantage to the furnace to lower the temperature for a short time, and yet be able, on the shortest notice, in case of a reaction taking place, to obtain instantaneously the highest possible heat. This,

it is claimed, would be possible with the valve arrangement described, for by allowing the cold blast to travel through a section only of the stove, it would soon exhaust all the available heat, while a large amount of heat is stored up in those sections which are closed, and is thus available for a sudden emergency. It will be seen, then, that by adopting this method, fewer stoves will be required, as the cleaning can be effected in five minutes, thus obviating the necessity of laying off the stove and waiting for it to cool, to have it thoroughly cleaned; also the fullest advantage can be taken of the available heating surfaces, and, moreover, the blast can be kept at a much more even temperature.

Two stoves at the Glengarnock Works have already been fitted with this arrangement, and, we understand, are giving excellent results, fully repaying the small outlay necessary for the installation. The firm are, indeed, so pleased with the result that we understand they intend applying the system to more of their existing stoves. As present day requirements necessitate a higher and more even temperature, which has made many firms consider the question of adding more stoves, and as a new stove could not be built for less than the outlay necessary for fitting several existing stoves with this arrangement, the same expenditure of capital would not only give better results in working the furnace, but would also involve less outlay in labor for cleaning. "Iron and Coal Trades Review," December 30, 1904.

The Scrap Problem. — For several years it has been obvious that a point could be reached sometime in the rapid expansion of the basic open-hearth steel industry when the current outcome of scrap would be insufficient, so that either a check would be administered to further increase in production, or development would be forced in the direction of the processes of basic open-hearth steel manufacture not involving the use of scrap. It has been, in fact, somewhat curious that the real danger point was not reached before this. It was not until 1897 that the million-ton mark was reached in the production of basic open-hearth steel, yet six years later, in 1903, the production was almost 5,000,000 tons. Roughly, the consumption of scrap by this industry increased in the six years by about 2,000,000 tons. It certainly was no small matter to find this additional scrap.

At this time, however, a combination of events has precipitated a scarcity of scrap which might otherwise have been longer in developing. In large measure, scrap is a by-product of iron and steel consumption. The bulk of the new steel rails put down replaces old ones. Where new machinery is installed, old machinery is frequently scrapped. New bridges replace old ones. If consumption of iron and steel were suddenly stopped, little scrap would come out. The present position is that there has been a period of slack consumption of iron and steel, during which little scrap has developed, followed suddenly by a remarkable expansion in the demand for steel. Naturally, the gradually increasing difficulty in finding scrap sufficient for the rapidly expanding demand for open-hearth steel purposes has been sharply increased.

The theory has sometimes been expressed that inasmuch as the total production of iron and steel is constantly increasing, the outcome of scrap will increase sufficiently to provide for all needs. This theory is untenable for several reasons. The basic open-hearth steel industry has grown far more rapidly than the general iron and steel business; every year, without exception, has seen an increase in the proportion of basic open-hearth steel production to total pig-iron production, or to total steel production. There is no reason to suppose that this growth will not continue, whether scrap can be found or not. Again, the earlier increases in the demand for scrap were met partly by decreasing the consumption in another channel. Formerly large quantities of crop ends, casting pit scrap, etc., were used in the Bessemer converter, either as a convenience or merely to get rid of it. This practice is, in the main, discontinued, and the scrap market already has the material formerly so used.

There is another element which in the long run will tell very emphatically. The general trend, although not marked, is pretty clearly towards a lighter average weight for all iron and steel consumed. Consumption of the heavy lines of steel products is increasing, but the consumption of the lighter lines is increasing more rapidly. These lighter lines are less likely to eventuate in commercially available scrap than the heavy ones. The production of wire, of sheets and of tin plates, has increased much more rapidly than the production of rails and of structural shapes. It is true the production of plates has increased

very rapidly, but chiefly on account of the steel car industry, and it will be long ere steel car material is found on the scrap heap. The heavy, scrap-producing lines constitute a smaller percentage of the total iron and steel production than they ever did before.

The problem is one which will solve itself. There is no hard and fast line between scrap and pig iron on the basic open-hearth. It is a question of output and of relative cost. Some producers, also, find it convenient to use direct metal, and require either less scrap or none at all. Then, as demand is more acute, there is a tendency to check the use of scrap in the rolling mill and the foundry. "The Iron Trade Review," January 12, 1905.

Dry Air in the Blast Furnace. — In purely industrial chemistry by far the greatest advance in 1904 is the use of cold air for blast furnaces. Until the quantity is calculated one is apt to overlook the large amount of water present in ordinary air. That observation applies not merely to the United Kingdom, which is admittedly moist, but in substantial measure to many other countries. It is said that the moist air of the Straits is helpful in tin smelting, because it acts very much as does steam in a producer; and if the prevailing temperature, 80° F. or thereabouts, is considered, it would be rash to deny the suggestion. But in a blast furnace there is quite enough neutral gas to be heated without adventitious water vapor, and gasification of solid fuel is only too free. Hence, incombustible vapor which can only aid the transference of fuel from the fusion zone to the stoves is altogether *de trop*, and is better eliminated. The thing has been done by so cooling the air that the major part of its water is deposited; the cost is inconsiderable, and is balanced by the lighter work of the blowing engines.

It may be properly debated what proportion of the undoubted economy is due to the removal of water vapor and what accrues from the greater effective capacity of the blowing engines. There is at the moment a considerable controversy between the advocates of these different views; the fact remains that a saving is secured. A further source of advantage has been indicated by Le Chatelier. The percentage of sulphur in the pig iron should be kept low, and on the proportion of this constit-

uent the use of cooled air freed from water has an important influence. Le Chatelier has shown that calcium sulphide normally present in the slag is not decomposed when treated in presence of dry carbon monoxide, but yields an appreciable quantity of sulphureted hydrogen when the carbon monoxide is moist or contains hydrogen. He deduces that if the coke of the charge is burned by means of dry air, the sulphur of the coke will pass without hindrance to the lime of the slag; but that should water or the hydrogen from its dissociation be present, there will be a contest between the lime and the iron undergoing reduction, to the advantage of the iron as an element yearning for combination, but to the sullying of its purity. It may well be that this possibility of limiting the sulphur content will prove almost as important as the increase of output of metal.

The whole idea is so delightfully obvious that ironmasters must be vexed at their oversight; the chemist is guilty, too, for he should have realized the uselessness of putting so much water through the fire, and should have considered whether that water could be cheaply extracted. Clearly, also, he should have considered the chemical action of water vapor from any source when injected into a blast furnace through the tuyère. Money considerations will demand a very careful scrutiny of the cost of this procedure, but the principle appears sound and worthy of the closest study. "The Engineer," January 6, 1905.

Drying Air for Blast-Furnace Work. — The question of the saving effected by drying the air supply in blast furnaces, recently discussed at the New York meeting of the Iron and Steel Institute, has since formed the subject of a communication to the French Academy of Science, by Messrs. Le Chatelier and Lodin.

According to the latter, if the air be heated to about 500° C., instead of drying it, the result will be the same, with less expense, two supplementary heaters being sufficient to obtain the desired temperature. In European blast furnaces, where the air is usually heated to 700–800° C., and the absolute quantities of heat utilized in working the furnace are generally much greater than in the Isabella furnaces, the relative saving that would be effected in the consumption of coke per ton of cast iron would, undoubtedly, be too small to justify the installation of expensive apparatus for drying the blast.

Le Chatelier states that the saving claimed on behalf of drying is due to the fact that the water vapor from undried air leads to an unproductive consumption of coke, by transforming it into a mixture of hydrogen and carbon dioxide, which escapes through the neck of the furnace; this reaction also absorbs a certain quantity of heat which has to be made good by an increased consumption of coke. The resulting loss, and, consequently, the saving to be effected by depriving the air of a portion of its moisture, can be calculated exactly. In the experiments in question, the quantity of water vapor condensed in the refrigerating chamber amounted to about 4 grains per cubic foot of air. The economy resulting from the drying process could not be more than 5 per cent, or one quarter the figures claimed. It is, therefore, evident that either the figures are inexact, or else the saving is due to some other cause. It is often found that inventors, though starting with an incorrect idea, still manage to achieve interesting results. This may be the case in the present instance.

In the view of M. Pourcel, the effects produced by the dissociation of water vapor may not be unreasonably included amongst the causes capable of affording an explanation of the saving observed at the Isabella Works as a result of drying the air blast. Finally, in the opinion of these experts, the results obtained at Pittsburg seem to have been influenced, to a considerable extent, by the comparatively low temperature — only 201° C. — of the undried air blast in the Isabella Works. "Iron and Coal Trades Review," January 20, 1905.

Steel at High Temperatures. — Prof. C. Bach has presented in the "Zeitschrift des Verein Deutscher Ingenieure" the results of an elaborate series of tests of the strength of steel at high temperatures. Bars from three different works were tested, these being distinguished by the letters O, K and M. Of the bars O, four were subjected to tensile tests at ordinary temperatures and successive lots of four to tests at the temperatures 200°, 300°, 400°, 500° and 550° C. At ordinary temperatures the strength of the steel was of bar No. 2, for example, 27 tons per square inch, and an ultimate extension on a gauge length of 8 inches, 26.3 per cent, and contraction of area 46.9 per cent. The results of the tests showed that the strength increased up

to 300° C. by about 3.17 tons per square inch, and from this temperature onward the strength fell, roughly in proportion to the temperature, to 13.1 tons per square inch at 550° C. The ultimate extension decreased from 25.5 per cent at ordinary temperatures to 7.7 per cent at 200° C., from which again it rose to 39.5 per cent at 550°. The contraction of area also fell at 200° C., but did not commence to rise until the temperature was above 300° C. In the case of the bars from the works distinguished by the letters K and M, tests were made by keeping the loads on for considerable time. This prolonging of the action of the load had no effect until the temperature reached 300° C., at which point it caused a slight decrease of strength, and at 400° and 500° a greater decrease. As regards the effect of prolonged loading on the extension and contraction between the temperatures of 300° and 400° C., it caused an increase in both, but from 400° the extension and contraction under prolonged loading decreased until at 500° C. they were lower by from 20 to 25 per cent than with ordinary duration of test.

Professor Bach draws the conclusion from his investigation that for steam boilers, piping, etc., the strength of steel should be tested at higher temperatures; and he is of opinion that this conclusion is justified, not only by his experiments, but from the well-known fact of the brittleness of steel when worked at a blue heat. "Iron and Steel Trades Journal," January 14, 1905.

A New Talbot Furnace Record. — All world's records for output and continuous run of open-hearth furnaces were broken during the last four months by the Talbot continuous process steel furnace of the Jones & Laughlin Steel Company, Pittsburg. A total of 20,680 gross tons of open-hearth steel was turned out, which leads all other records by 3,000 tons. The former record of 18,000 tons was held by the Talbot furnace. A feature of the performance of the furnace, which ended January 15 at noon, and which is considered the most important, is the length of time the metal was kept in the furnace without the furnace being relined. The life of the ordinary 50-ton open-hearth furnace is not within two weeks as long as that of the Talbot furnace.

The great demand for steel for the mills of the Jones & Laughlin Company has caused the Talbot, the six open-hearth furnaces and the three Bessemer converters to be rushed day

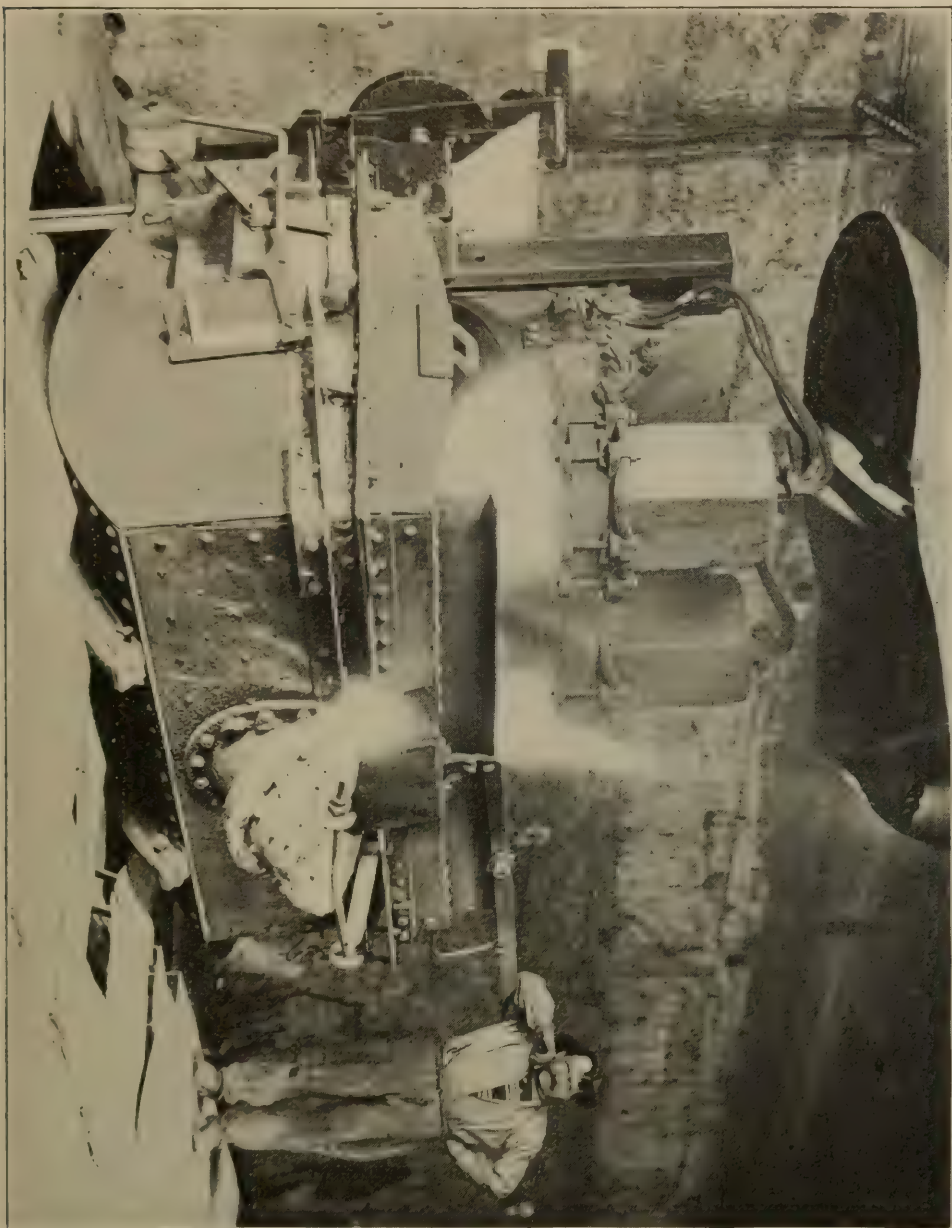
and night, and at this rate the supply was not equal to the demand and several of the finishing mills were run light. The mills of the company running at this rate have required 15,000 tons of steel per week. The success of the Talbot furnace has caused the erection by the company of four new furnaces of the same type, the first of which will be put in heat during the coming month, the others to follow at intervals of one or two weeks. When these furnaces are completed the company will have a steel capacity of 3,300 tons a day.

The man who has made the Talbot furnace a success in operation and who has in a way caused a decided change in the methods of steel manufacture is John McConnell, the present superintendent of the Talbot furnace. "Iron Age," January 26, 1905.

Wear of Rails. — At the October meeting of the New England Street Railway Club, Mr. H. M. Steward, roadmaster of the Elevated Division of the Boston Elevated Railway, read a remarkable paper on the wear of rails on the elevated and subway tracks of Boston. Wear upon the curves of these tracks takes place at a rate for which there is no precedent on steam roads. Diagrams were shown of the rails before and after use, the wear of the heads of rails made of ordinary commercial steel being over ¾ inch after forty-four days' use. Various kinds of steel have been experimented with and the wear greatly reduced. On a certain grade of hard steel the wear has been brought down to .18 inch, and on nickel steel to .53 inch after 204 days' use. Manganese steel shows .19-inch wear after 947 days' use.

Another direction in which the wear is different from that in steam tracks lies in the formation of corrugations on the surface. These corrugations seem to be largely due to the skidding of the wheels, although this is but a partial explanation. An engine driver may be kept spinning for some time on the rails without material injury to the rails, whereas, on the Boston roads, such spinning will cut the rails in two. Similar corrugations appear on other electric roads, but to nothing like the extent that they do on the Boston tracks. They are found only on curves, but, curiously enough, only on curves of comparatively large radius. Thus they are not found at all on curves of less than 500 feet radius, but with radii of over 1,000 feet they are

very troublesome. Trains stalled on grades have worn grooves in the track which have made them helpless and made help necessary to move them. "American Machinist," January 19, 1905.



Héroult Furnace. — The accompanying illustration shows a recent type of an Héroult furnace for the electrical production of iron and steel, in which the stationary crucible has been replaced by a tilting one, thus doing away with the tap holes for

slag and metal. This furnace is used by the Société Electro-métallurgique Francaise at Froges, France. It consists essentially of two vertical movable electrodes dipping into the substance to be heated and melted. The furnace may be used both for the extraction of iron from its ore and for the refining of cast iron by the pig and scrap or pig and ore processes.

British and American Use of Basic Steel. — London "Engineering," reviewing the statistics of the American iron trade in 1903, directs attention to the attitude of consumers of steel in this country toward basic steel in contrast with the hesitancy of engineers in Great Britain. It says: "We have before had occasion to call attention to the fact that basic steel is viewed in the United States with much more favor than is the case in this country, and have expressed the opinion that our engineers might do well to show more confidence than they appear to do in this material, perfectly reliable as it has proved to be when manufactured with care and under proper supervision. Old customs and usages die hard in this country, however, and basic steel is still looked upon with suspicion in many quarters. That this view is not taken by our American cousins is shown clearly by the fact that in 1902 there were made in the States 4,496,533 tons of open-hearth steel by the basic process and 1,191,196 tons by the acid process, while in 1903 the production by the basic process amounted to 4,734,913 tons, and by the acid process to 1,094,998 tons. There was a decrease of a little over 8 per cent in the production of acid open-hearth steel ingots and castings in 1903 as compared with 1902, but an increase in the production of basic steel of 5.3 per cent. These figures speak for themselves." "The Iron Trade Review," December 22, 1904.

The Iron and Steel Institute. — The annual general meeting of the Iron and Steel Institute will be held at the Institution of Civil Engineers (London), May 11 and 12, 1905. The autumn meeting will be held in Sheffield on September 25 to 29, 1905.

REVIEW OF THE IRON AND STEEL MARKET

The month of February has seen some improvement in demand for pig iron and for finished steel products, but the market has not reached the intense activity which prevailed for a couple of months before the holidays. There may be some doubts whether the iron trade can maintain the enormous pace it has set for itself, a pace far in excess of anything that has been maintained for any more than the briefest period in the past. A month ago we stated that by early in February the country would be making pig iron at the rate of 21,000,000 tons annually; the rate is now probably close to 21,500,000 tons. The expectation is that production will be further increased, but the industry can experience quite a decline and still round out 1905 with by far the greatest production ever shown in a calendar year.

The market generally has been stationary, but some advances have been made, including the important ones of \$2.00 a net ton on structural shapes and a like advance on plates. Galvanized sheets have been advanced \$2.00 a ton. The advances in black sheets, wire products, tin plates and merchant steel bars, which have been more or less expected, have not been made.

Pig Iron. — The pig-iron market has been almost stationary. Prices in some districts are a trifle higher than a month ago, and in others a trifle lower. Sales have been fairly heavy, except as regards foundry and forge grades in the Pittsburg district. There have been heavy sales of basic by Eastern furnaces, while Southern furnaces have also made good sales, including sales aggregating 40,000 tons to a large merchant firm. The United States Steel Corporation early in the month bought 25,000 tons of Bessemer in the valley market, and later purchased an additional 5,000 tons, all at the former price of \$15.50, valley. As this is written the corporation is making its March purchase, of 40,000 tons. Some weakness was developed in the Pitts-

burg market on foundry iron sales to a prominent consumer but the incident was not regarded as serious. Prices now stand as follows: F.o.b. valley furnace: forge, $15.15; No. 2 foundry, $16.00; Bessemer and basic, $15.50. At Pittsburg: Forge, $16.00; No. 2 foundry, $16.85 to $17.00; Bessemer and basic, $16.35. At Birmingham: Forge, $12.75; No. 2 foundry, $13.50 to $13.75. At Philadelphia: Standard gray forge, $15.75 to $16.25; No. 2 foundry, $17.50 to $17.75; basic, $16.50. At Chicago: Northern No. 2 foundry, $17.50; malleable Bessemer, $17.50.

Steel. — The crude steel market continues very strong, and in some instances premiums as high as $3.00 have been paid above the official prices of $21.00 for billets and $23.00 for sheet bars, f.o.b. Pittsburg. Mills are very much behind in their shipments and it is difficult to buy steel for either early or extended delivery. The scarcity is somewhat greater for open-hearth steel, for sheet bars and for forging billets than it is for ordinary Bessemer billets.

Shapes. — At the meeting of the beam pool on February 16 a straight advance of $2.00 per net ton or one-tenth cent a pound was made, to apply on all sales except those based on options already out. There has been much closing of options in consequence, but not a great deal of new business. Prices are now as follows: Beams and channels 15-inch and under, zees, and angles 2 x 3 to 6 x 6 inclusive, 1.60 cents per pound; tees, 3-inch and larger, 1.65 cents; beams and channels over 15-inch, 1.70 cents, all in carload and larger lots, f.o.b. Pittsburg.

Merchant Bars. — The market is unchanged on iron bars, with common bars of recognized quality still quoted at 1.65 cents, f.o.b. Youngstown. In steel bars there has been an advance from the price of 1.40 cents to 1.50 cents, which covers both Bessemer and open-hearth bars, half extras, in carload and larger lots, f.o.b. Pittsburg.

Plates. — At the meeting of the plate association on February 16 a straight advance of $2.00 a ton was made. The mills are well filled with specifications, which come chiefly from the car builders. Prices are now as follows: 6¼ to 14 inches wide, inclusive, 1.50 cents per pound; over 14 inches and not over 100 inches wide, 1.60 cents, for tank quality, quarter-inch and heavier, carload and larger lots f.o.b. Pittsburg, with extras for

quality, for lighter than quarter-inch and widths beyond 100 inches.

Sheets. — On February 9 the following advances were made by the leading interest and have been followed by the independents: Galvanized sheets, $2.00 per net ton; blue annealed sheets, $1.00 per net ton; galvanized corrugated roofing, 10 cents per square. An advance in black sheets has been looked for but has not been made yet. Mills are booking some additional business and are well filled with orders. Prices are as follows: No. 28 gauge, carload and larger lots, f.o.b. Pittsburg, 2.30 cents for black and 3.45 cents for galvanized; galvanized corrugated roofing, No. 28 gauge, 2½-inch corrugations, carload lots to good buyers, f.o.b. Pittsburg: $1.65 per square for painted and $2.95 per square for galvanized, a square being 100 square feet.

Scrap. — The tone of the market has been a trifle easier, dealers being more anxious to sell. The supply of scrap, however, is quite limited, the outcome being small at this season. A sale of 4,000 tons of heavy melting stock was made to the Carnegie Steel Company at $16.25, but the general asking price is $16.50 to $16.75. Current quotations on other grades are as follows: Sheet scrap, $14.75 to $15.25; cast-iron borings, $10.50 to $11.00; cast scrap, $15.00 to $15.25.

STATISTICS

Pig-Iron Productions. — The following information dealing with the productions of pig iron in the United States in 1904 were published in the "Bulletin of the American Iron and Steel Association" for February 1, 1905:

Total Production. — The total production of pig iron in 1904 was 16,497,033 gross tons, against 18,009,252 tons in 1903, 17,821,307 tons in 1902, 15,878,354 tons in 1901, 13,789,242 tons in 1900, 13,620,703 tons in 1899, and 11,773,934 tons in 1898. The following table gives the half-yearly production in the last four years in gross tons:

Periods	1901	1902	1903	1904
First half . . .	7,674,613	8,808,574	9,707,367	8,173,438
Second half . .	8,203,741	9,012,733	8,301,885	8,323,595
Total	15,878,354	17,821,307	18,009,252	16,497,033

The production of 1904 was 1,512,219 tons less than that of 1903. The production in the second half of 1904 was 150,157 tons more than that of the first half. The causes of the decline in production in 1904 as compared with 1903 are so well known that they need not be dwelt upon in this connection, but it is worthy of mention that the last four months of 1904 showed great and steadily increasing activity in production. This rate of production was continued and exceeded in January of the present year.

Classified Production. — The production of Bessemer and low phosphorous pig iron in 1904 was 9,098,659 tons, against 9,989,908 tons in 1903, a decrease of 891,249 tons.

The production of basic pig iron in 1904, not including charcoal of basic quality, was 2,483,104 tons, against 2,040,726 tons in 1903, an increase of 442,378 tons.

The production of charcoal pig iron in 1904 was 337,529 tons, against 504,757 tons in 1903 and 378,504 tons in 1902.

The production in 1904 was 167,228 tons less than in 1903 and 40,975 tons less than in 1902.

The production of spiegeleisen and ferromanganese in 1904 was 219,446 tons, against 192,661 tons in 1903. The production of ferromanganese alone in 1904 amounted to 57,076 tons. One company produced 946 tons of ferro-phosphorus in 1904.

A significant feature of the above statistics is the increased production of basic pig iron in a year of generally reduced production.

Unsold Stocks. — The stocks of pig iron which were unsold in the hands of manufacturers or which were under their control in warrant yards and elsewhere at the close of 1904, and were not intended for their own consumption, amounted to 408,792 tons against 623,254 tons on June 30, 1904, and 591,438 tons on December 31, 1903. The American Pig Iron Storage Warrant Company held 55,350 tons of pig iron in its yards on December 31, 1904, of which 17,700 tons, included above, were reported to us as being still controlled by the makers, leaving 37,650 tons in other hands. Adding this 37,650 tons to the 408,792 tons noted above gives us a total of 446,442 tons that were on the market at the close of 1904.

Furnaces. — The whole number of furnaces in blast on December 31, 1904, was 261, against 216 on June 30, 1904, and 182 on December 31, 1903. The number of furnaces in blast at the end of 1904 was 45 larger than on June 30 of the same year and 79 larger than on December 31, 1903.

RECENT PUBLICATIONS

Les Alliages Metalliques (Metallic Alloys), by Léon Guillet. 232 $6\frac{1}{2} \times 10$-in. pages; 118 illustrations including 20 photomicrographs; paper covers. Vve Ch. Dunod. Paris. 1904. Price in France, 7.50 francs. — Metallurgists and engineers are at the present time greatly interested in metallic alloys, and these invaluable metallurgical products are being subjected to searching investigation. For these researches the latest and most scientific methods have been employed and it will not be necessary to recall here how very fruitful they have been. Any one, however, who has looked into the matter must realize that we are only on the border line of a field which promises a rich harvest as a reward for further and careful investigation, and many are eagerly looking for any valuable contribution to this important subject. In the book we have before us they will find such a contribution. The author's work is too well known by our readers to call for more than a passing mention. Although still a very young man, having devoted but a few years to this special study, his written contributions have been many and of a high degree of merit. Mr. Guillet's experiments are always conducted with method, intelligence and skill and the presentation of his results is always clear, logical and instructive. In the book we are now reviewing, he describes with his usual lucidity our present knowledge of the constitution of alloys, bringing the subject down to date. His first chapter is of an introductory character and deals with the phase rule with which metallurgists must now be familiar if they wish to obtain a good grasp of the nature of alloys and of their close relation to solution and other chemical systems. The following titles of the other chapters will indicate the contents of the book: "Curves and Surfaces of Fusibility," "Cooling Curves," "Microscopic Metallography," "Electrical Resistance," "Thermo-electricity," "Magnetism," "Dilatations," "Mechanical Properties," "Density," "Specific Heats," "Electromotive Force of Dissolution," "Chemical Study of

Alloys," "Heats of Formation," "Application of the Phase Rule" and "Conclusions." Each chapter is subdivided into three parts, the first one devoted to a description of the principles involved, the second to a description of the methods employed and the third to some examples. The author says in his preface that this first volume is devoted to the theory of the subject and that in a few months a second volume will be published dealing with the various alloys and their application. His aim will be to show clearly what important assistance may be rendered by science to the metallurgical art and what intimate bonds exist between theory and practice. The publication of Mr. Guillet's second volume will be awaited with much interest.

American Tool Making and Interchangeable Manufacturing, by Joseph V. Woodworth. 535 6 × 9-in. pages; 601 illustrations. The Norman W. Henley Publishing Company. New York. 1905. Price, $4.00. — The aim and contents of this excellent and timely book are well and truthfully described by the publisher's announcement from which the following is quoted:

"This book is a complete practical treatise on the Art of American Tool Making and System of Interchangeable Manufacturing as carried on to-day in the United States. In it are described and illustrated all of the different types and classes of small Tools, Fixtures, Devices and Special Appliances which are or should be in general use in all machine manufacturing and metal working establishments where economy, capacity and interchangeability in the production of machined metal parts are imperative.

"All of the tools, fixtures and devices illustrated and described have been or are used for the actual production of work, such as parts of drill presses, lathes, patented machinery, typewriters, electrical apparatus, mechanical appliances, brass goods, composition parts, mold products, sheet metal articles, drop forging, jewelry, watches, metal, coins, etc.

"The treatment of each tool described and illustrated is such as to enable any practicable man to design, construct and use special tools, dies and fixtures, for the rapid and accurate production of metal parts, interchangeably.

"To the machinist, tool maker, designer, diemaker,

superintendent, manager and shop proprietor this book shows the twentieth century manufacturing methods and assists in reducing the expense and increasing the output and the income. A book on the system of interchangeable manufacturing — the system that has won for the United States the industrial supremacy of the world."

There is little doubt that this important treatise will be received with the favor it deserves and prove of invaluable assistance to tool makers and tool users. The publishers also are to be congratulated for the care which they have bestowed on the preparation of the book, the typography, printing and binding being all that could be desired.

The Non-Metallic Minerals, by George P. Merrill, head curator of geology in the United States National Museum, and professor of geology in the Corcoran Scientific School of Columbian University. 414 6 × 9-in. pages; 32 full-page plates, mostly half-tones, and 28 figures in the text. John Wiley & Sons. New York. 1904. Price, $4.00. — The author describes with much authority the occurrence and uses of the non-metallic minerals, exclusive of gems, building stones and marbles. The treatment is methodical and exhaustive. This work will certainly be welcome by metallurgists and geologists, as the matter, which it so well presents, is not to be found in so available a form in any other publication. The book is well printed and very attractively and substantially bound.

Producer Gas, by A. Humboldt Sexton, professor of metallurgy in the Glasgow and West of Scotland Technical College. 214 6 × 8½-in. pages; 32 illustrations. The Scientific Publishing Company, Manchester, England. Price, $4.00. — The title of this book does not suggest its entire scope, for it treats not only of producer gas, but of gaseous fuel in general. The author gives special attention to the principles on which the production of gaseous fuel depends. Typical producers are described at length and in an appendix many of the latest forms are mentioned. The book is a timely one; it has much to be commended and it will be found of much value to the increasing number of metallurgists and manufacturers interested in gaseous fuel.

Cements, Mortars and Concretes, by Myron S. Falk, instructor in civil engineering in Columbia University in the City of New York. 176 6 × 9-in. pages; numerous illustrations. M. C.

Clark. New York. 1904. — The purpose of this treatise has been to set forth as concisely as possible the physical properties of cement and cement mixtures, with principal reference to those properties which concern the engineer. The author has abstracted, classified and summarized in this book the reliable data scattered in numerous publications and has filled some gaps with data of his own. The subject is treated under the following headings: "General Properties of Cements," "Physical Tests of Cements," "General Physical Properties," "Elastic Properties in General," "Tensile Properties," "Compressive Properties," "Flexural Properties." The usefulness of the book is not to be denied and it will be welcomed by engineers and others interested in cements.

New York Air Brake Catechism, by Robert H. Blackall. 254 4 × 6-in. pages; 75 illustrations. The Norman W. Henley Publishing Company. New York. 1904. Price, $1.25. — The author, who also wrote the "Westinghouse Air Brake Catechism," presents in this book a very clear description of the New York Air Brake. The book was written with the idea of furnishing information, not only for those who are interested in handling the brake, but for those as well who are concerned in its installation and maintenance. It contains nearly 1,000 examination questions and their answers.

Geological Survey of Canada. Report on the Nickel and Copper Deposits of the Sudbury Mining District, Ontario, Canada, by Alfred Ernest Barlow. 236 6½ × 10-in. pages; many full-page illustrations, mostly in half tones; 5 maps. Ottawa. 1904. Price, 25 cents. — This report deals with the origin, geological relation and composition of the nickel and copper deposits of Sudbury, Ontario. The report also includes brief references to the character and extent of all the more important nickel deposits of the world, with a general statement of their production and methods of smelting and refining. Details of the mining, smelting and refining operations of the Sudbury ores are furnished, as well as complete statistical tables of production, prices, uses and composition of the nickel of commerce. The author writes that Canada has at last realized the true importance and value of these mines and has, within the last year, taken her position, from which she will not recede, of being the largest producer of nickel in the world.

The Brass World and Platers' Guide, Vol. I, No. 1, January, 1905. 36 7 × 10½-in. pages; illustrated. The Brass World Publishing Company, Bridgeport, Conn. Subscription, $1.00 per year; single copies, 10 cents. — This new monthly magazine is devoted to the art of refining, alloying, casting, rolling, founding and electroplating of all the non-ferrous metals. It is edited by Erwin S. Sperry, who for several years edited "The Metal Industry." This initial number contains short editorials and articles of interest to the producers, workers and users of non-ferrous metals.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

777,450. FURNACE CHARGING CRANE. — Clarence L. Taylor, Alliance, O., assignor to the Morgan Engineering Company, Alliance, O. In a charging and discharging apparatus, the combination with a trolley of a frame depending therefrom, a truck mounted on wheels, the latter having bearing on vertical tracks on the frame, means for moving said truck vertically, tongs-carrying frame pivoted to the truck so as to have a rocking movement thereon, and means for actuating said tongs.

777,559; 777,560; 777,561 and 777,562. PROCESS OF FORMING PIPE. — Charles B. Stravs and John N. Jager, Minneapolis, Minn., assignors of one third to Anthony Huhn, Minneapolis, Minn. A process of forming pipe consisting in distributing the pipe material in molten or liquid condition by centrifugal force upon the inner surface of a rotating distributing-chamber and feeding it in regulated quantities from the surface of said chamber on to the surface of a concentric rotating mold.

777,728. HEATING-FURNACE. — James H. Haskins, San Diego, Cal., assignor of one half to International Harvester Company, Chicago, Ill. In a heating and tempering apparatus, in combination with a furnace and cooling receptacle, a rotating shaft having a series of tongs circumferentially mounted thereon in such relation to said furnace that rotation of said shaft carries said tongs alternately in and out of said furnace, means for intermittently advancing and arresting said tongs, means for feeding articles to said tongs during the interval of arrest, means for delivering the articles to the cooling receptacle and means for automatically operating said feeding, carrying and delivering mechanism.

777,750. APPARATUS FOR INDICATING THE MAGNETIC CONDITION OF HEATING METALS. — George W. Sargent, Reading, Pa., assignor to the Carpenter Steel Company, Reading, Pa. The combination with a metal-heating apparatus of a magnet arranged to include in its field the heating metal, and means for indicating the response or non-response of the heating metal to the magnetic influence.

777,814. FURNACE. — William Simpkin, Orange, N. J. In a furnace, a combustion-chamber having outer walls of continuous brick and an inner lining of firebrick or other suitable material, said inner lining separated from said outer walls by air spaces or pockets divided by firebrick headers.

777,927. Ladle. — Richard H. Stevens, Munhall, Pa. A ladle having a complete supporting bottom shell, a cast-metal false bottom lying on the bottom shell and a refractory lining extending over the false bottom.

778,194. Electric Furnace. — Henry M. Howe, New York, assignor to Eimer & Amend, New York. An electric resistance-furnace, consisting of two internally grooved blocks and a cover, in combination with a resistance element in the grooves of the blocks.

778,195. Manufacture of Billets. — William B. Hughes, Philadelphia, Pa. A mode of forming billets, consisting in subjecting to shearing and compressing action successive sections of an ingot, which extend from top to bottom of said ingot, each section retaining its proportionate share of the crop end of the ingot.

778,269. Process of Electric Welding. — Adolph F. Rietzel, Lynn, Mass., assignor to Thomson Electric Welding Company, Lynn, Mass. A herein-described improvement in welding links or other endless forms by an electric welding process applied to one side of the link, consisting in drawing out the welded side to remove the stress developed in the bended side by the pressure applied to effect the weld.

778,493. Valve for Blowing Engines. — Albert T. Keller, Wilkinsburg, Pa. A blowing engine having formed in and transversely of its heads cylindrical valve-chambers, each in two sections and having openings in their exterior portions in combination with open-ended hollow cylindrical valves, movable across the space or openings between said sections.

778,614. Gas-Producer. — Samuel T. Wellman, Charles H. Wellman and John W. Seaver, Cleveland, O., assignors to the Wellman-Seaver Engineering Company, Cleveland, O. The combination in a gas-producer of hollow stirring or agitating arms, a rotating element of the producer carrying the same and having a partition whereby it is divided into two chambers one of which communicates with said hollow arms, pipes projecting into the hollow arms and communicating with the other of said chambers, and means for supplying water to one of said chambers and conveying it from the other.

778,827. Poker for Gas-Producers. — William B. Hughes, Wissahickon, Pa. A poker comprising a hollow stoking-bar, hollow trunnions connected therewith, and a cap having passages connected with the interior of said bar and trunnions.

778,899. Method of Forming Blocks of Ore for Metallurgical Purposes. — Arpád Ronáy, Budapest, Hungary. A method of rendering material capable of use for metallurgical purposes by converting it into blocks by means of pressure and the exposure of the blocks to the action of combustion gases containing carbon, which consists in subjecting the material, which may be in a finely granulous form or in certain cases in the form of powder, to a pressure increasing gradually to a very high degree, so that the air entirely escapes from the material during the pressing operation, and the pressure is only carried at the last stage to such a degree as to render the material plastic.

778,017. Ingot-Charging Crane. — Clarence L. Taylor, Alliance, O., assignor to the Morgan Engineering Company, Alliance, O. In ingot-charging apparatus, the combination with a bar and two movable racks carried thereby, of ingot-grasping tongs, and means actuated by said racks for opening and closing the tongs.

779,037. Method of Smelting Ore. — James Gayley, New York, N. Y. A method of smelting ore, which consists in subjecting the ore with carbonaceous fuel to a blast of dried air, the burden of fuel being less than the normal burden by an amount materially greater than that which would be required to dissipate the eliminated moisture.

779,074. Frame for Covers for Crucible Steel-Melting Furnaces. — Charles W. Cowen, Reserve township, Allegheny County, James H. Turner, Pittsburg, and Robert C. McLellan, Washington, Pa. In a frame for a cover for crucible steel-making furnaces, four arched bars joined at or near the ends by plates, and near the center by a plate; and between the center and end plates by four other plates, two on each side of the center plate, which join the four arched bars into two pairs; being substantially the main body of the frame.

779,171. Manufacture of Tool-Steel. — John A. Mathews, Syracuse, N. Y., assignor to Crucible Steel Company of America. High-speed steel containing not less than 10 per cent of vanadium.

779,307. Process of Manufacturing Mineral Wool. — Thomas B. Parkison, Muncie, Ind. A process for the production of mineral wool which consists in subjecting the molten slag or scoria to the action of smoke.

779,769. Means for Utilizing the Waste Gases from Furnaces. — Corydon L. Cole, Minneapolis, Minn., assignor, by direct and mesne assignments, to the Waste Heat Utilizing Company, Minneapolis, Minn. The combination, with a steam boiler, of a shell or casing having tube-sheets or heads and having one end open to the atmosphere, a pipe for delivering the products of combustion direct from the boiler to the shell or casing at a point removed from the air-receiving end of said shell or casing, an escape-pipe for the products of combustion near said receiving end, means for inducing currents of air through the tubes, and means for conveying the heated air from the tubes.

779,844. Electric Furnace. — David R. S. Galbraith, Auckland, New Zealand, assignor of one half to William Steuart, Auckland. In an electric furnace for treating iron-sand and other refractory ores and substances comprising an incased furnace recessed to accommodate electric connections in circuit with a source of electric energy and having the sides of its fusing zone stepped internally with inclined chutes, a plurality of non-conducting intercepters mounted within the furnace at the stepped fusing zone and arranged in superposed relation and adapted together with such stepped parts of the furnace to deflect the material under treatment successively to the next lower intercepters and with electric conductors leading into the fusing zone at the ends of each intercepter, and a plurality of V-shaped troughs perforated at their bottoms and serving to direct the materal in thin streams longitudinally central of the

under series of intercepters and conductors, whereby the shower charge of the material will be caused at the time of each of its interceptions to complete and act as part of the electric circuit.

GREAT BRITAIN

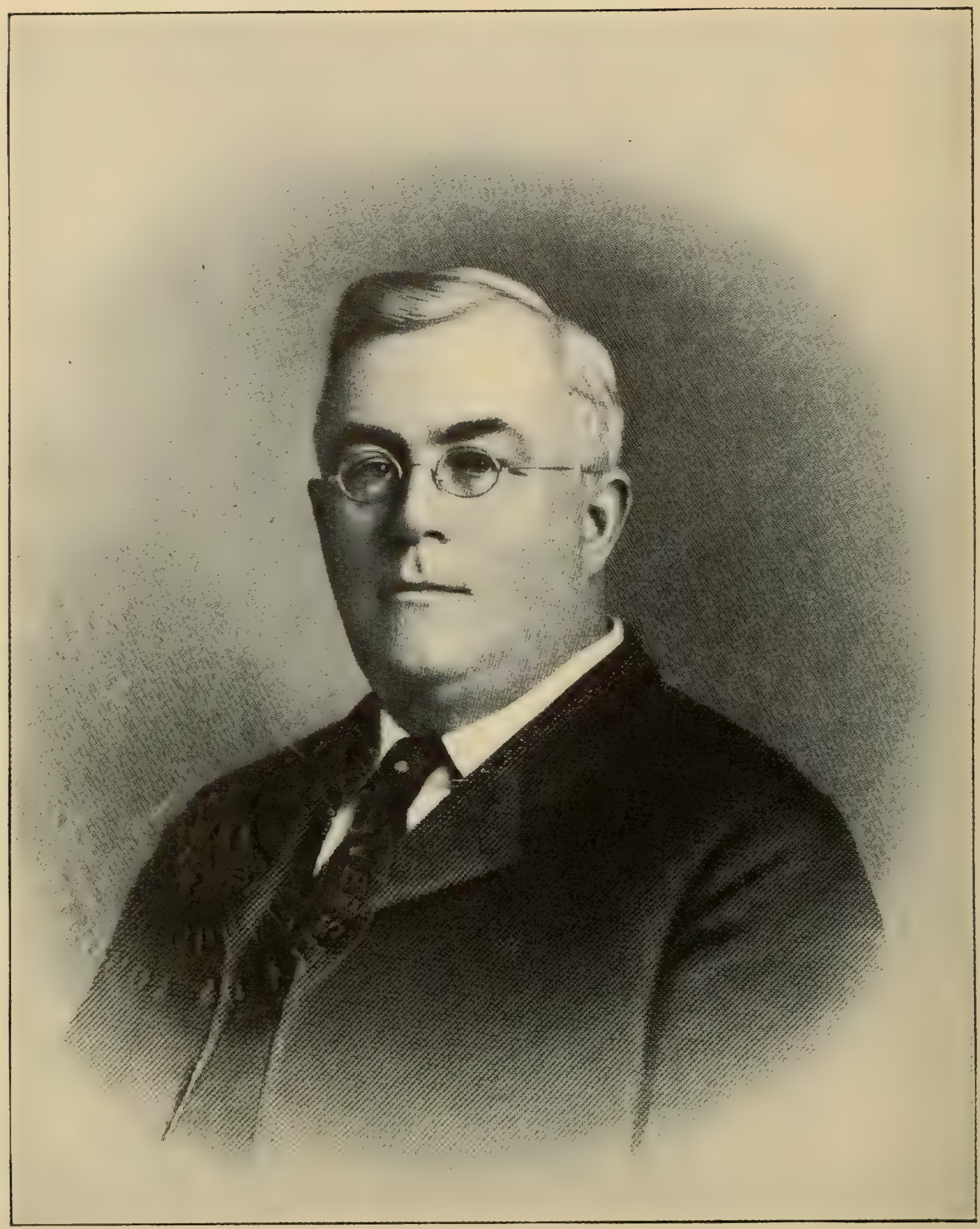
23,861 of 1903. Chromium-Nickel Alloy. — Société Anonyme la Neo-Metallurgie, Paris, France. An alloy of iron chromium and nickel made in electric furnace, free from carbon, to be used in manufacture of chrome and nickel steels.

14,985 of 1904. Iron Mixer. — Compagnie du Reacteur Metallurgique, Paris, France. Improvement in mixers used in steel plants and in copper and nickel refining plants, whereby, by means of jets of air, etc., the amount of preliminary refining is increased.

24,924 of 1903. Manganese Silicon Alloy. — La Neo-Metallurgie, Paris, France. Producing in an electric furnace a compound or alloy containing from 50 to 90 per cent of manganese and from 10 to 50 per cent of silicon very free from carbon, sulphur and phosphorus.

755 of 1904. Using Iron Borings. — W. J. Foster, Walsall. Method of injecting iron borings and turnings along with the blast in blast furnaces.

6,945 of 1904. Bronze Alloy. — A. Jacobsen, Hamburg. An alloy of iron, nickel, copper and aluminum for making a bronze of great tensile strength.



SAMUEL THOMAS WELLMAN

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The Iron and Steel Magazine

" . . . . . . *Je veux au mond publier
d'une plume de fer sur un papier d'acier.*"

Vol. IX April, 1905 No. 4

CASE-HARDENING *

By DAVID FLATHER

DEFINITION. — The term "case-hardening" naturally implies the hardening of the skin of an article, and in order to fully understand the process and its object we must briefly consider the facts and laws upon which it is founded.

Carbon has a very great affinity for iron, which is limited only by their combining power on the one hand and the conditions of their contact on the other.

Carbon combines with iron at all temperatures above faint red heat, and advantage is taken of this fact in the production of steel by cementation — in fact, the process of case-hardening is in reality incomplete cementation followed by water or oil hardening.

Hardening. — By the term "hardening" we understand the production and fixing of the maximum hardness which any given steel is capable of yielding. All steels are brought to their greatest state of hardness by being heated to certain tempera-

* Read before the Cycle Engineers' Institute, Birmingham (England), April 23, 1903.

Although published some two years ago we take great pleasure in reproducing this article, with the author's kind permission, because of its unusual excellence. We feel confident that our readers will derive much profit from it and will appreciate the author's clear and practical treatment of the interesting and important operations of case-hardening. — Ed.

tures, followed by more or less rapid cooling in such fluids as are most suitable for the kind of steel and the work it has to do.

Object of Case-Hardening. — Before proceeding to review the process it may be useful to set forth clearly the advantages we seek to obtain through its employment, and follow this by a brief consideration of the material on which we propose to operate.

For many purposes in cycle work we require articles to have a perfectly hard surface, and yet to be of such a nature that there is no chance of their breaking in use. In many instances this result can be obtained with high-class crucible steel, but for axles, cups, cones and many similar parts, it is extremely difficult to obtain perfect hardness combined with great resistance to torsional, shearing or bursting strains. For such purposes nothing can meet these requirements so fully as can be done by means of case-hardening.

The greatest risks in the employment of all steel often occur during its treatment by the consumer, and whether it be the finest cast steel, or only common Bessemer, it is of first importance that it should be carefully and properly treated with a view to the work it has to do.

At one time it was the custom to sneer at case-hardening as being the product of more or less uncertain guesswork. Whatever may have been the fact years ago, it is very true that case-hardening is now no less certain in giving good results than is the employment of high-class crucible steels.

Material. — Both iron and mild steel have been employed as material for case-hardening, but this is the "Steel Age," and iron has, I think, long passed its day. The steel employed should be prepared, selected and controlled from the beginning, with the object of suiting it to its requirements. There are, of course, many points relating to its composition and treatment by the producer which can only be gained by long experience and by study of the requirements, but, as you will understand, I cannot treat of them here. Suffice it to say that the steel used should be low in carbon and capable of absorbing more carbon with great uniformity when heated under proper conditions; it should contain a minimum of deleterious impurities, and be perfectly sound and free from mechanical faults or weaknesses caused by overheating during the manufacturer's processes.

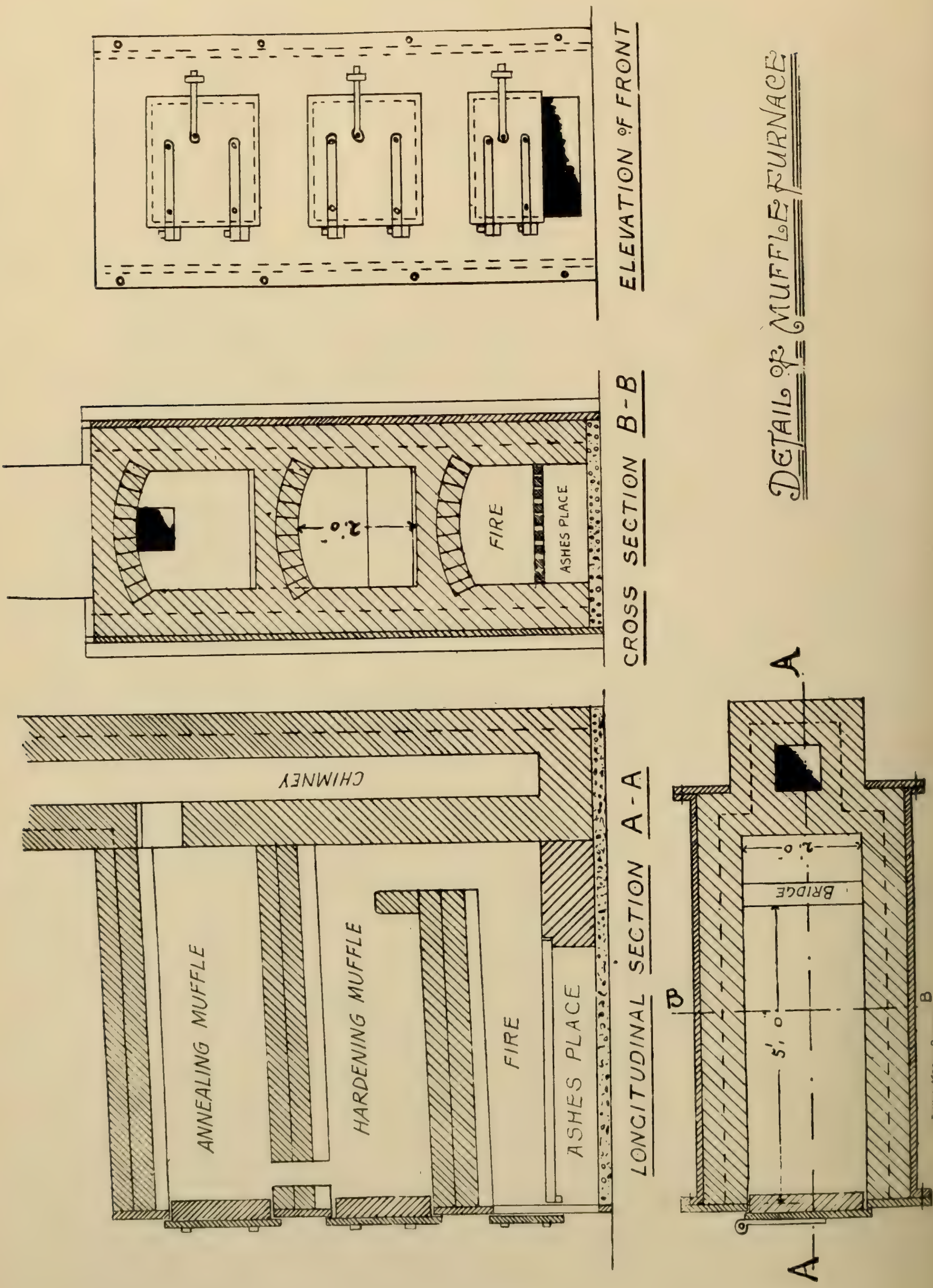
Outline of the Process. — The process of case-hardening consists, then, in bringing the steel or iron articles into contact with carbon in closed boxes or pots, and raising them to the requisite temperature for a sufficient length of time; afterwards the articles are reheated and cooled by quenching in oil or water.

Equipment

The Furnace. — This should be so constructed as to be capable of being raised to a full orange heat (1000° C.) and maintained at that heat with great regularity. It should be so constructed that neither the fuel nor the direct flame can come in contact with the charge — that is to say, that the flames should uniformly impinge on the sides and roof of the muffle in such a manner as to raise them to a high temperature, thus heating the contents of the muffle by radiated and not by direct heat. A furnace designed on this principle not only gives the best result, but is also most economical in the matter of fuel. The muffle chamber and flues must, of course, be constructed of firebrick, and the doors should fit closely and also be lined with firebrick. It is important that there should be a small peep-hole in the door, with a cover-plate; a hole 1½ inches in diameter is quite large enough. This latter is really a most important detail, as it provides against the need of opening the doors in order to judge the heat, and is indeed the most accurate means of estimating the temperature by the eye. The furnace must be fitted with a reliable damper plate or other effectual means of controlling the draught.

I give a drawing of a small furnace which may, I hope, be useful as a guide for the erection. The cost of such a furnace is about £35. I have an upper chamber in this furnace, and though this is not necessary for case-hardening, it may in a small works be found useful to have such a chamber and employ it while case-hardening is being done, for the insertion of any articles which require annealing. This will add only very slightly to the amount of fuel used.

Generally speaking, coal is the fuel employed for case-hardening, but there can be no doubt that, at least for large works, where a number of furnaces are kept going, gas-fired furnaces should give every satisfaction, not only as regards


ELEVATION OF FRONT
CROSS SECTION B-B
FIRE
ASHES PLACE
2'.0"
DETAIL OF MUFFLE FURNACE
LONGITUDINAL SECTION A-A
CHIMNEY
ANNEALING MUFFLE
HARDENING MUFFLE
FIRE
ASHES PLACE
A
A
B
B
BRIDGE
2'.0"
5'.0"
THICK METAL PLATES
SECTIONAL PLAN
ON HARDENING MUFFLE

economy in working, but in the amount of control which can be kept over the temperature.

Hardening Pots. — These are made in both cast and wrought iron — the former being cheaper in first cost, but the latter bear reheating so many times that they are cheaper in the end. The pots should not be of too large dimensions, or there is great risk of articles in the middle of a charge not being cased to a sufficient depth. In my opinion no pot should be above 18 inches by 12 inches by 11 inches for such articles as axles, pedal pins and the like; while for small articles like cups, cones, etc., 12 inches by 10 inches by 8 inches is large enough. The pots should each have a plate-lid fitting closely inside.

Carbonizer. — Perhaps in no part of the process has there been so many differences of method as in the question of the carbonizing material. At one time nearly every case-hardener had some secret and wonderful composition or mixture to which he attributed his success, and when he failed to get good results he followed the usual course and blamed the steel. However, those bad old days are nearly gone, and the secret mixtures have nearly all passed to the country blacksmiths who invented them.

The carbonizers in general use at the present day are animal charcoal, bones and one or two other compositions sold under various names, and consisting of mixtures of carbonaceous matter and certain cyanides or nitrates. For very slight hardening, cyanides alone are still found very useful, but no great depth of casing is ever attempted with these.

Theoretically the perfect carbonizer should be a simple and pure form of carbon, and for once theory and practice are agreed. I have made many hundreds of experiments, and have tried all kinds of mixtures, but I have always found good charred leather to give the most certain and satisfactory results. I beg you to note that I say "good" charred leather, and I do this because most of what is sold under this title is very bad — it is not fully charred, and very often it is not leather; therefore I strongly advise that charred leather should be bought only from some firm who are actually in the leather or some allied business, and who use this trade as an outlet for their scrap leather. Even under such circumstances it is important to keep a strict watch over the deliveries, and especially to keep a good lookout for traces of copper and steel rivets, — a sure evidence of old boots

or old belting, — neither of which is a desirable constituent in the composition. Buy the leather coke in lumps and have it powdered in your own works, taking care that it is not contaminated in the process, and that by the time it is required for use it is perfectly free from moisture.

Clay. — As clay must be used for a luting round the pot lid, and is also frequently used for stopping off portions to be left soft, it is important to see that a good clay is used, and that it is free from grease. I mention this because I once had much difficulty in tracing to its origin a great irregularity in the hardening turned out by one of my friends. We tested separately every part of their method, and only after having tried everything I knew, I thought of the clay — asked where they got it from, and, when they said from the mortar mill, I saw at once the source of the trouble. I asked to see their clay stock, and, sure enough, found among it several lumps of cog grease. This had been worked up into the clay, and, directly it got into the muffle, melted; part ran into the pot and did the damage. I did not investigate the action any further, as our object was achieved. A change in the clay brought about a satisfactory change in the hardening results. Therefore I advise that a careful watch be kept on the clay supply.

Reheating Muffle. — As all case-hardened articles have to be reheated before quenching, it is important that a suitable furnace should be employed for the purpose. It is not advisable that the reheating should be done in the case-hardening muffle, unless it is run specially for the purpose and at a lower heat. If possible a small gas muffle should be used for reheating, and indeed for nearly all hardening work. A properly constructed gas muffle can be regulated with great exactness, and this is very important in all hardening; fortunately we have not to go out of Birmingham to fill such a want.

Quenching Liquids. — A good supply of clean water is very necessary, and where oil is used care should be taken to have as large a tank as possible.

The Hardening Shop. — Although the arrangement of the shop hardly comes within the scope of this paper, yet it may be worth our while to note certain points which might be useful in arranging such a shop. The whole shop should have a north aspect, and all strong light be avoided; indeed, it is better to

make the light as subdued and as nearly constant as possible. This is important because, under our present way of working without the aid of pyrometers, the only means of regularly judging the heat is by means of the eye, and it is easier to estimate a heat-color in a constant shadow than in a strong light.

The Process

Having enumerated the equipment of a case-hardening plant we may now proceed to consider the process as it is, or should be, carried out.

Packing the Pot. — The carbonizer having been thoroughly dried and reduced to a fine powder, a layer of not less than 1½ inches in depth is placed in the hardening pot and well pressed down. Upon this are placed the articles to be hardened. Care must be taken to leave sufficient space all round each piece to prevent its touching the others or the walls of the pot — a space of 1½ inches should be sufficient. Another layer of carbonizer is then put in and well pressed down, taking care not to displace any of the articles already packed, continuing until the pot is nearly full, and then finishing off with another layer of 1½ inches at the top. The object in view must be to make the contents of the pot as compact as possible, consistent with a sufficiency of carbonizer in contact with the articles. The more solidly a pot is packed the more effectual is the exclusion of air. The lid is then put on and the joint all round well luted with clay. By the time the proper number of pots have been filled, the furnace must have been raised steadily to the full working heat.

Furnace Heat. — According to my experience the proper heat for case-hardening is 1000° C., or a full orange "heat color," and this should be maintained with great regularity throughout the operation. The length of time occupied in carbonizing is regulated by the depth of casing required, and indirectly by the dimensions of the article. To this I will return later.

At the close of the carbonizing period the pot is withdrawn from the furnace and placed in a dry place, where it is allowed to become quite cold. It is then opened, the articles taken out and brushed over to remove all adhering matter. If the pot has been properly packed and luted up, the articles should be quite white, or at least have only a slight film or bloom of a

deep blue color; the denser and more inclined to redness is the surface the more imperfect has been the packing and sealing of the pot.

Water Hardening. — The case-hardened articles are now placed in a muffle furnace and steadily raised to a good cherry-red heat (800° C.), and then quenched in cold or tepid water or oil according as the purpose of the articles requires. They should remain in the cooling liquid until they are quite cold right through the body of the metal, thus completing the process.

Analysis of the Process

Having already considered the essentials of a proper case-hardening shop and its equipment, it remains now to go more thoroughly into the different points which arise in connection with the process itself.

Packing the Pot. — "The carbonizer must be finely powdered." It is very necessary that there should be absolute contact between the surface to be case-hardened and the carbonizer — the larger the particles the more likely are there to be air spaces left, which result in uneven and irregular casing. For a similar reason, a sufficient distance between the articles must be allowed, and all danger of contact with the pot guarded against.

Furnace Heat. — I have said that the proper heat for case-hardening is a full orange color heat, or 1000° C., but I may here qualify this by saying that the heat may, to some extent, be altered to suit the purpose in view. In order, however, to thoroughly understand and take advantage of this fact we must consider more fully the theory of the process. With this purpose in view we must first understand, so far as possible, the relations between carbon and iron in the cementation process, and, following this, the modification of it known as the case-hardening process.

Carbon and iron have strong affinity, the one for the other, and when brought into contact at suitable temperatures a combination takes place in which certain carbides of iron are formed. The physical properties of iron are changed by this combination, hardness and tensile strength being raised in proportion to the amount of carbon absorbed. (By the term "iron" in this case we may understand iron or any steel capable of combination with carbon within the limits of the process.)

The object of the cementation process as carried out by the maker of crucible steel is to convert bars of commercially pure iron into steel containing from .80 to 1.5 per cent of carbon, and, so far as possible, for the resultant steel to be uniform in constitution right through the bar, while the case-hardener wishes to put only a skin or case of hard steel, leaving the center soft and tough. The quantity of carbon which can combine with iron is governed, first, by the temperature, and, secondly, by the period of time the action endures. The absorption of the carbon commences when the steel reaches a low cherry-red heat (700° C.); it begins, of course, at the outer surface and gradually spreads until the whole of the steel is carbonized. The length of time this requires depends upon the thickness of the metal being treated. The percentage of carbon absorbed is governed by the temperature, and although the increase of carbon is not in uniform proportion to the rising temperature throughout, it is, perhaps, sufficient for our present purpose to note that at 700° C. iron, if completely saturated, can contain no more than about .50 per cent carbon; at 900° C., about 1.5 per cent carbon; and at 1100° C., about 2.5 per cent. These results, however, are only obtained when the whole section of the iron has received all the carbon it is capable of absorbing at the given temperature, and is therefore in a state of equilibrum. From this, I think, you will see that if the process is stopped before the action is complete, the central parts of the iron must contain less carbon than the outside, and upon this fact the process of case-hardening is founded.

As already stated, the object of case-hardening is to give certain articles a dead-hard surface, while yet retaining a very mild and tough center, thus uniting the maxima of hardness and of strength.

Steel Used. — At this point we should consider the essentials of the material to be used, and for this purpose I may refer you to my previous paper. Briefly, however, I may say that iron has been almost entirely superseded by steel, both for cycle and most engineering purposes, but it is of great importance that the steel employed should be of such a nature that, combining sufficient purity with absolute regularity of composition and condition, it is capable of absorbing a uniform amount of carbon, and, at the same time, the body of the steel remaining in the soft

core shall yield its highest results in tenacity and strength after it has passed through the process of case-hardening. From this point onward we have to bear in mind the fact that in all other treatment of steel we have only one steel to deal with at once; in case-hardening we really have to treat two steels, inseparably connected, but differing in composition, and to treat them in such a manner as to get the best results from both; that is, of course, the core of mild steel and the case of hard steel. In the case we require such a percentage of carbon as will yield a dead hard surface when properly hardened, and in the core an extremely tough steel which will take a very severe bend without breaking. First, then, we have to determine at what temperature we are to work the cementation part of the process, and to decide this there are several points to be strictly observed.

1. The carbon in the case must be about .80 per cent.

2. The case must be neither too thick nor too thin.

3. The temperature must not be so high as to overheat the mild center.

4. The core must be of the greatest possible strength.

Although I have given separate requirements, we must consider them all together.

A temperature of 1000° C. if continued to saturation would yield a carbon percentage of about 2.5, but if interrupted at any stage short of saturation the skin would contain less carbon and the center still less, on account of the process of diffusion being still in progress.

If we take two pieces of $\frac{5}{8}$-inch diameter round mild steel and heat one of them with a carbonizer at a cherry-red heat and the other at a bright orange heat for six hours, the first will be cased to a depth of about one thirty-second of an inch, and the other to a depth of nearly one sixteenth of an inch, while the amount of carbon taken up will be about .50 and .80 per cent respectively. So that, as far as regards the hardness of the skin, the piece cased at the higher temperature gives the best result. From this we learn that a temperature of 1000° C. will give us sufficient hardness of case.

We have next to find which temperature has the least hurtful effect on the mild steel core, and this can best be found by heating pieces of the mild steel, at varying temperatures at and above the selected one for the same length of time, using lime

or other inert substance in the pot instead of a carbonizing material; afterwards reheating and quenching in water. Suppose, for example, we take three pieces — heating at 1000°, 1300° and 1500° C., or full orange, white and bright white respectively. We shall find that those at 1300° and 1500° break very short and have lost nearly all their original tenacity, while that at 1000° appears tougher and altogether stronger than before.

Having arrived at a knowledge of the right temperature, it remains now to inquire as to the length of time requisite to yield a sufficient depth of case, and though I can give you an average figure of the results I have obtained in my own experimental work, yet, owing to slightly different methods of working and appliances, and also the variation in shape and dimension of the articles to be cased, the only reliable way of obtaining definite results is by trial and error. At a full orange heat a bracket cup of ordinary dimensions would in two hours be hardened one thirty-second of an inch deep, and a bracket axle eleven sixteenths of an inch diameter in six hours would have a case one sixteenth of an inch deep. From this it will be seen that the speed of penetration is not in exact proportion to the time of heating; this is most probably due to the fact that the outer surface, being in direct contact with the carbonizer, first must become saturated, while each succeeding zone has to receive its carbon by diffusion — a slower process. I have said nothing as to the mode of counting the time, but from what I have already stated it will be clear that it will be correct to start counting from the moment when the pot reaches a bright red heat, but provided the furnace can be relied on for regularity of heating, the time can be taken from putting in the pot — adding from thirty to forty-five minutes according to the size of the pot.

Water Hardening. — We now arrive at that part of the process where a most important improvement has been made — I mean the final hardening by quenching in water. When, many years ago, I first took up the serious study of the case-hardening process I found great irregularity and consequent distrust of the process, and after many experiments was successful in finding a solution of the difficulty. At that time it was customary at the end of the carbonizing period to open the pot and fling the contents headlong into a tank of cold water — here

and there some of the more careful workers took each article separately, but direct from the pot, and plunged it into water. These latter obtained better results, but even they had a great deal of trouble in the way of breakages and want of regular hardness. Finding that axles taken singly from the pot and quenched were better than those quenched in bulk, and that if allowed to cool down to cherry red they were better still, an application of the old rule to harden on a rising heat, led to the now established principle of allowing the pot and its contents to become quite cold, afterwards reheating to cherry red and quenching in water. By this means we obtain a case of great hardness with a very tough core — that is, of course, provided a suitable steel is employed.

To understand the reason of this improved method of working we must remember that the exterior of the steel is now of about .80 per cent carbon, and that steel of all kinds raised to and maintained at the high temperature employed for case-hardening will, unless subjected to mechanical work, show evidence of overheating, being very brittle, liable to easy fracture, and though quenched in water and consequently hardened, the metal has little or no cohesion and readily wears away. Steel so hardened breaks with a very coarse crystalline fracture in which the limits of the case are badly defined. It is known that when steel is gradually heated there is a certain point at which a great molecular change takes place, and that perfect hardness can only be obtained by quenching at this critical point. If quenching takes place below the critical temperature, the steel is not sufficiently hard; if above, though full hardness may be obtained, strength and tenacity are lost in part or completely, according as the critical temperature is exceeded by much or by little. This critical point lies between 750° and 800° C., or cherry-red color heat. It may be asked why it is not sufficient, when taking the article out of the pot, to allow it to cool down to cherry red and then quench it. To this I would answer that the high temperature has already created a coarsely crystalline condition in the steel, and that until it has become quite cold and has again been heated up to the critical temperature a suitable molecular condition cannot be obtained. When steel is cooled, whether slowly or not, it bears in its structure a condition representative of the highest heat it was last subjected to. From

this, I hope, it will be quite clear that in case-hardening, as in all other methods of hardening, the steel must be quenched on a rising heat. I may add that for certain purposes there is some advantage to be gained by quenching direct from the pot if followed by reheating to cherry redness and again quenching, but this I will remark upon later.

Having, I hope, made clear the reason for complete cooling after carbonizing, followed by reheating for water hardening, we may proceed to consider the proper manner of carrying this out. We must remember that the case-hardened article now consists of two kinds of steel, one being mild steel of a temper that will not harden in water, and the other which is capable of becoming glass hard when properly heated and quenched. The critical points of the two steels are not of course the same, that of the hard steel being slightly lower than that of the soft steel. Therefore, bearing in mind my previous statement that to obtain complete hardness in the skin and the maximum of strength in the core, they must both be heated to their critical temperature before quenching. Now, as the critical points of the two are not identical, and as they must be raised at least up to those points, it follows that one of the steels will have to be heated considerably above its proper hardening point, or the other not heated sufficiently to reach its greatest tenacity. We have, therefore, to find which of the two will result in the least risk. If we heat the article to the critical point of the hard steel case we do not reach the critical point of the mild core; and, on the other hand, if we raise to the proper heat for the mild we exceed that of the hard steel. As our object is to obtain hardness combined with strength, and as the strength lies almost entirely in the core, it follows that we must heat sufficiently to remove the coarse crystallization of the core, thus exceeding the critical point of the case, and in doing so, while we obtain very nearly the maximum hardness we lose very little of the strength of the case and obtain the maximum strength of the core. I have gone rather fully into this point, and, it may be thought, without necessity, as the temperature is almost universally judged by the eye. But my object in doing so is to point out how important it is for the second heating to be sufficiently high to obtain the best result. The case-hardened steel as it comes from the

pot cannot be rendered hard and strong without a sufficient second heating. If a test piece or a finished article when broken shows a more or less coarsely granular fracture and having the casing irregularly defined, it is an almost certain evidence that the second heating has not been sufficiently high; and this perhaps emphasizes the importance of using test pieces wherever possible.

From these remarks we shall see the importance of accuracy with respect to the temperature for reheating, a good cherry-red color heat being the correct one for all case-hardened work. Also it is well to note that this reheating should, so far as possible, be rapidly performed, and once the article becomes uniformly of the right temperature it should be immediately quenched in oil or water. Any prolonged soaking, even though it be at a proper heat, should be avoided, especially in articles, like cups, or cones, having to resist any lateral strains. The reason for this is as follows: A mild steel of proper composition, if subjected to prolonged heating just above its critical point, will develop a gray fibrous fracture having very marked laminations. Such a structure, though weaker than a finely crystalline one, will in the case of solid articles such as bracket or pedal axles, which are subject to torsional or shearing strains, still have a sufficiently high safety limit; but if, on the other hand, the same structure exists in a cup or cone, the strain bears upon the steel in such a manner that, owing to the weakness of the laminations, it is unable to withstand the test. This gray or fibrous fracture, once developed, cannot be satisfactorily altered by any further heat treatment without deteriorating the case, and therefore precautions should be taken to see that it is avoided altogether.

Tempering. — It is sometimes desired that the hardness of the case shall be slightly tempered, but I cannot say anything in favor of it. The object of tempering is, generally speaking, not so much to reduce the hardness as to increase the strength, but we must bear in mind that the strength lies in the core of mild steel, and that even if the strength of this can be increased by tempering (which I doubt), you can only use the "temper color" given by the hard case as an indicator, and this can be no guide to the proper tempering heat of the core. Now, supposing that we are able to increase the strength of the mild core by tempering, it is highly probable that the proper tempering heat, instead of being represented by a "straw color," would be

at least "dark blue" "temper color," if not "visible red" heat color, and this of course would take away perhaps 50 per cent of the hardness of the case.

Stopping-off. — It is frequently required that axles and spindles shall be left more or less soft in the middle in order to set or straighten them after hardening, and for this purpose it is usual to coat with clay such portions as require to be soft. Though often successful this is by no means a certain measure to take, owing to the shrinkage of the clay when dry and heated. This shrinkage, though it may not be sufficient to allow the carbonizer to come in direct contact with the steel, yet allows the access of the carbonic oxide gas which forms the atmosphere within the heated pot, and this gas is capable of case-hardening steel almost as completely as direct contact with carbon. Indeed, if it were not for several important practical difficulties, case-hardening by means of this gas alone would be an ideally perfect process. Knowing the risk of clay stopping, other means — more or less successful — have been tried; but, to my mind, in all cases where soft portions are required, the only certain method is to leave the parts full size, and then, after case-hardening but before water-hardening, to remove the superfluous metal by machining.

Extreme Hardness. — It may be desirable for special requirements to make extreme hardness the first consideration. In such cases the case-hardening heat may be raised to bright yellow (1250° C.), and then, at the end of the period, instead of allowing to become cold, take the pot from the furnace, and when the articles have cooled a full red heat, quench in water or oil, afterwards reheating to full cherry and again quenching. Though by this method the absolute strength is much reduced, a considerable increase of hardness is obtained.

Having discussed the process of case-hardening, it may be useful to consider briefly the principal faults which occur, and which may be detected by examination of the test pieces.

Before long we may hope to be able to make a most searching examination, not only of the test pieces, but also of the finished articles, by means of the microscope. I am endeavoring to formulate a reliable system of examination as applied to case-hardening results, but regret that the work is not at present in a sufficiently advanced state to be laid before you.

As I have already stated, it is always of great importance to put a test piece in every pot and to treat this in the same manner exactly as the articles being hardened. It is, of course, most useful to take one of the articles themselves and use it as a test piece, and, where possible, this should be done. The tests to be applied come under the heads of "hardness" and of "strength." The hardness, in the absence of any special scientific tests, is proved by the use of the file; for this purpose a smooth saw file should be employed, and is a test too well known to need any repetition here. I may, however, remark that when using the file, and it appears as if the test piece were not fully hard, before deciding that this is really the fact it is well to examine the file used, when it may be found that what were thought to be filings from the test piece are really the powdered teeth which have been forced away from the file. Sometimes the extreme surface is quite easily touched by the file and the articles are declared to be soft; if, however, the filing is continued, a dead-hard surface is found beneath. This has been caused by the action of the air on the steel, either by incomplete sealing in the pot, or more probably by want of care in reheating.

If, for example, the muffle door has been left open, the air, acting on the heated steel, has decarburized the outer skin, leaving it soft. If articles having such a fault are afterwards submitted to rather deep polishing or grinding, there will, of course, be little harm done.

The use of the file will also detect irregularity of hardness; but for this there is no remedy — prevention is the only cure.

Proceeding next to the examination of the test piece by fracture, we have first to judge its strength by its resistance to impact, its tensional, torsional or shearing capacity; but as a cycle works is not as a rule furnished with a testing laboratory, we need only consider such rough-and-ready tests as we may apply in the smith's shop. It is true that such tests are at best very crude (even when the results are compared one with another), consisting usually of blows by a hammer upon the test piece, afterwards judging either by the number of blows or the angle of bend as to whether the test piece be satisfactory or not. It should not, I think, even in a small works, be difficult to construct, at slight expense, a means of testing which would make it possible to obtain reliable results under fixed

conditions. Thus, a constant weight falling from a constant height, if systematically employed, would make it possible to decide on the strength of all articles or test pieces of any given pattern, and thus create a standard. For this purpose would be required a couple of timber uprights with guiding strips, and say 12 feet high, together with beds of shapes varied to suit the different articles, and a series of weights proportioned to the size of the articles to be tested. A pawl catch placed 10 feet from the bed would then hold up the weight, which, when released, falling on the test piece, would give a constant blow, which could be repeated until either the article broke or was considered to be of sufficient strength.

Judging Fractures. — We have next to consider the fractures of the test pieces, and in doing this I may repeat that the structure of steel, as shown either in the fracture in or the polished and etched section, contains a certain record of at least the last heat treatment through which it passed.

(*a*) Perfectly case-hardened steel will, when fractured, show a case of extremely fine white grain, and which is clearly defined and of very regular depth, while the core is finely granular and of a distinctly metallic luster.

(*b*) The case, instead of having a fine white dry appearance, is full of minute brilliant specks, and is not so clearly defined. The core is much coarser and more sparkling, and the test piece would break easily, being more or less rotten. Such a fracture shows either that the article was quenched direct from the pot, or that, if heated a second time, it was not raised to a temperature sufficiently high to re-arrange the structure caused by the high temperature of case-hardening.

(*c*) The outer zones of the case are coarser, as in *b*, while the remainder, and also the core, are very little coarser than *a*. This is the result of too high a temperature in reheating. An article having such a structure would, though of full hardness, wear into little pinholes and specks, and in certain articles of small dimensions very easily break.

(*d*) The case appears as in *b*, but the core is gray and fibrous, or when broken laterally shows very marked laminations. This is caused by too high and too long heating before quenching.

Such, then, are the principal faults which are to be detected by inspection of the fractures, but I must remind you that this

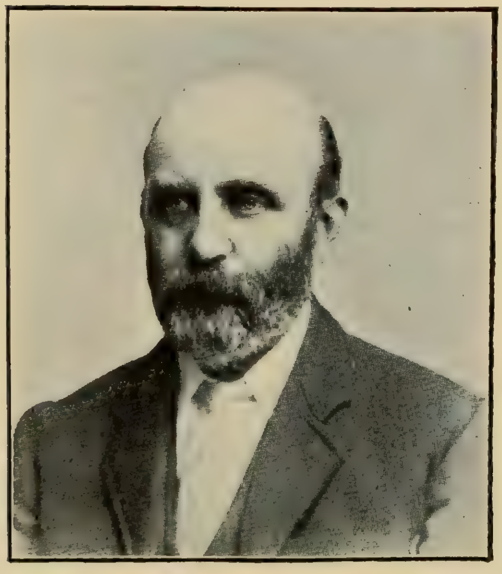
list does not include any faults which are the result of defects in the steel employed. I have throughout taken it for granted that a good and reliable brand of steel is used.

As a last general recommendation, I may say that the success of the process depends, first, on the use of pure material, and, secondly, having once established a proper system of hardening, absolute regularity in carrying it out.

SCIENCE IN THE IRON FOUNDRY *

By J. E. STEAD

THE object of writing this paper is to direct the attention of founders and others to certain necessary and fundamental conditions for carrying out foundry practice to-day, and to suggest a few definite lines which metallurgical chemists in foundries should follow in order that their services may have the maximum value to both themselves and their employers.



Arrangement of Stocks in the Stock Yard.—Those who prefer to work on what may be called the hand-to-mouth principle can have little or no use for a chemist, and cannot possibly make the best of progress, for they are completely at the mercy of the sender of the pig iron, who, if he supplies foundry iron of the grades specified, may send material with greatly varying properties.

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* Read before the Cleveland Institution of Engineers, February 20, 1905. Slightly abridged.

This interesting article has been especially revised by the author for publication in the *Iron and Steel Magazine.* Some appendices describing "American Specifications for Foundry Iron and Foundry Materials" have been omitted, on the ground that most of our readers are probably familiar with them. — Ed.

Many works are so arranged that it is impossible to keep stocks, and they have no alternative but to feed their cupolas direct from the trucks or from the twenty or thirty tons of metal they have room to stock.

Their remedy is to demand an analysis from the maker of each brand, and accept only such iron as contains the specified quantity of silicon, etc. (See Appendices II and III.) It has been the practice of hematite pig makers to test each cast and to stock according to the analysis, and there should be no difficulty in doing the same thing at furnaces making foundry iron.

Many furnaces in the future are likely to be driven much more rapidly than is the practice to-day, and as rapid blowing tends to the production of iron low in silicon, if such iron be sent out indiscriminately with the same class of iron made in the more slowly driven furnaces, the result will be chaos in the foundry.

Up to the present, foundry pig has been stacked, when put into stock for warrants or other purposes, solely according to the grade of the fracture and not to analysis. I maintain that the time has come when this old-time custom must be swept away, and it is the buyers of foundry iron only who have the power to effect the change, for by demanding chemical composition as well as fracture numbers, the makers will be obliged to meet them, but certainly cannot be expected to do so if it is not asked for.

When ordering pig metal it is very important that the analysis be demanded, and also, where possible, that each day's delivery shall be taken from a single cast of iron, or if more than a single cast is sent in any one delivery, to have the trucks ticketed, so as to show the cast and analysis.

The stock yard should be arranged in such a way that there is easy access from the cupola to the stacks of pig, and equally easy access from the railway sidings. Where many brands are used, the area required will necessarily be greater than when a small number are stocked. The arrangement of the stacks must depend upon the space available and the work done. The system I should prefer is to make long rectangular narrow stacks, 20 to 30 feet in length, 5 feet in width and 5 feet in height. These should run parallel with the railway. In unloading the iron from two or three trucks at a time, the pigs should be

spread equally over the 25 by 5 feet area, and this system should be continued when laying down the iron from sets or other trucks of the same brand, until the height of the stack of 5 feet is reached. Samples having been taken, these should be sent to the laboratory for testing purposes, and no iron should be used from any stack until its average composition is known. In taking metal from them to melt in the cupola, what is removed should represent an average of every layer. This is done by working from one end of the rectangular heaps to the other.

When the first stacks are being worked up, duplicate stacks should be made, preferably opposite those of like brand, on the other side of the tram or railway.

The scrap iron should be stocked according to its fracture, and average analyses be made of the stacks laid down. Two separate stacks should be sufficient, one of good gray heavy scrap, and one for small rusty material.

Sampling Pig Iron for Analysis. — When a consignment of pig iron arrives at the works, before taking any sample, note should be made whether or not the metal in the trucks is apparently regular or of mixed quality. If regular, two or three pigs off each truck should be selected. If irregular a larger number. These should be broken and note taken of their fracture number. Drillings should be taken from the side, half way between the bottom and top of the pigs. After the drill has penetrated one eighth of an inch below the skin, what is removed in this way should be rejected and the drill then bored to the center, and the clean drillings reserved for analysis. The drillings from the several pigs should be mixed in equal proportion, and the mixed sample be thoroughly cleansed with a magnet to eliminate any grains of sand which may have accidentally fallen into it.

The importance of taking drillings from the position given will be recognized when it is known that the sulphur is always much higher at the top than at the bottom of the pigs. Indeed, I have found three or four times as much in the upper layer as was present in the bottom layer. Guy Johnson, in one of his trials, found an average of 0.024 per cent in the lower part, 0.108 per cent in the central portion, and 0.148 per cent in the upper layer, the center portion approximating to the average. The more manganese present in the pig the greater is the flotation of the sulphide of manganese to the top.

It will be readily conceived that in consequence of the property of the sulphur compound to float off, the metal which runs into the pig molds should have less sulphur than the same material when it leaves the furnace. This is actually the case, and the difference is usually the greater when the amount of manganese present is larger. I have met with scum on the surface of basic pig which contained 5 per cent sulphur.

The American Association for the standardization of methods of testing suggest taking four pigs from every car and boring with a large drill each fractured end at a point midway between the center and the side. This method has the advantage that there is less liability of sand getting into the sample, and there is less trouble in drilling. Both methods should give the same average sample.

The Effect of Metalloids on Cast Iron

Effect of Silicon. — In 1875, I made an experiment to ascertain the effect of heating to whiteness a pure white iron, free from silicon, in a crucible lined with ganister. The result was that the white iron was turned gray. Analysis proved that some of the carbon had acted on the silica of the ganister according to the equation $SiO_2 + 2C = Si + 2CO$, with the result that nearly 1 per cent of silicon was found in the metal. On melting this metal with a little iron ore the silicon was removed and the metal again became white. These experiments were clear evidence that the silicon had been responsible for throwing the carbon out of combination with the iron.

In 1885, Mr. Charles Wood, one of our most esteemed past presidents of the Cleveland Institution of Engineers, conducted experiments in order to test a statement which I had made to the effect that if he melted together two almost unsalable products of his blast furnaces,— glazed iron and white iron,— he would obtain a good soft gray iron, quite suitable for foundry castings.

The result of Mr. Wood's trials were given in a paper read before the Iron and Steel Institute in 1885.

Glazed pig iron with 4.43 per cent silicon was melted with white pig iron in varying proportions, with results which Mr. Wood considered to be rather surprising, for the castings produced were as good as could be wished for. Previous to the

publication of this paper the rôle which silicon played had not been understood in England. Professor Turner had, however, three months previously, shown in a paper read before the Chemical Society that the addition of silicon to pure cast iron, or a compound of iron and carbon alone, increased its tenacity.

In 1886, Mr. Fred Gautier, Paris, in a paper on "Silicon in Foundry Iron," read before the Iron and Steel Institute, stated that the experiments just referred to, proving that white pig iron with a suitable addition of silicon could give gray castings of the best quality, was an entirely new departure in metallurgy, the practice of the most experienced founders being based on a totally different view. He also stated that in his opinion "this discovery is perhaps even more important than that of the basic process itself, and the discussion which followed upon it did not seem to me adequate to the importance of the subject."

The so-called discovery referred to was the fact that silicon acted indirectly in causing the combined carbon to assume the graphitic condition.

It was not long after the publication of Professor Turner's and Mr. Wood's paper that glazed pig iron, previously unmarketable, was sought after by founders, and a great demand sprung up for ferro-silicon. Although it was Mr. Charles Wood who first made trials on a commercial scale by mixing silicon pig and white pig iron with the production of a gray mixture, it must not be forgotten that Professor Akerman of Sweden, had, thirteen years previously, shown the tendency of silicon and combined carbon to replace each other, and that had founders and others read his papers with intelligence they might have made advantageous use of his observations. Dr. Percy in his work on "Iron and Steel," published in 1864, page 131, says: "It has long been observed — in the first instance by Septrom — that carbon in gray iron in which much silicon exists, say 2 to 3 per cent, is wholly or nearly so in the graphitic state. It is not, however, to be hence inferred that silicon has displaced the carbon," from which it would appear that Dr. Percy did not thoroughly understand the rôle played by silicon.

Referring to the remarks regarding the work of Professor Turner and Mr. Wood, Professor Ledebur, in a paper published later, and read at the Darlington meeting of the Iron and Steel Institute, says:

"The presence of silicon in pig iron consequently diminishes its capacity for taking up carbon, and, on the other hand, it is necessary for the formation of gray pig iron. Pig iron free from silicon remains white even after slow cooling, and gray pig iron changes into white if its contents of silicon is abstracted. . . . From this the deduction follows directly, that if molten white pig iron has the opportunity afforded it of taking up silicon, it will change into gray pig iron."

It would appear, then, that both Professor Akerman and Professor Ledebur have the credit of previously having published the exact rôle which silicon plays in cast iron, but it must be remembered that neither of the gentlemen had suggested the mixing of silicon pig with white iron. Indeed, Professor Turner in his work on the "Metallurgy of Iron" (1900), page 196, says: "The practical application of silicon in the foundry is due chiefly to C. Wood, Middlesbro, who was working in this direction with Mr. Stead in 1885."

It is well known by pig-iron manufacturers that gray pigs with the lowest percentage of silicon are the most difficult to break, and a fair idea of what amount of silicon is present may be formed by watching the breaking of the pigs. Nos. 1, 2, 3, hematite pigs, with 1.5 per cent silicon, are only broken with difficulty; with 2.5 per cent silicon, more easily, and with 3 per cent silicon and above, very easily.

It will be understood, then, that silicon directly weakens iron and makes it less resistant to shock.

Glazed pig iron contains high silicon. The peculiar glazy appearance of the fracture is due to the cleavage faces of the metallic matrix, which are not seen in pigs containing little silicon, for the track of the fracture when the matrix is strong is mainly through the cleavages of the plates or curved sheets of graphite. The cleavages of the matrix are white, whilst those of graphite are black.

Silicon has a much stronger attraction for iron than carbon, a fact easily proved by melting white Swedish iron with 20 per cent silicon in a closed graphite crucible. The whole of the carbon will be expelled and float to the surface of the metal. The white metal remaining will be silicide of iron, free from carbon.

I believe it was Mr. Edward Riley who first discovered that

metal with 20 per cent silicon contains no carbon and is quite white.

Iron containing 4 per cent silicon cannot be carburized by the cementation process. It is necessary to have a melting heat before carbon will pass into such iron, and at the point of solidification what is absorbed will be thrown out of solution, and no combined carbon will remain in the cold metal.

Valuable papers on silicon and iron have recently been published by Mr. Guillet and another by Mr. Baker, which should be carefully studied by every metallurgist.

Effect of Sulphur. — The *direct* effect of sulphur on the strength of cast iron has long been regarded as injurious, but no reliable experiments have been carried out to determine the truth of this in Europe. Indeed, the only trials made on correct principles, so far as I know, are those of Mr. Guy Johnson and Mr. Keep, both Americans. As will be seen, the evidence appears to show that provided sulphur does not keep the carbon from separating as graphite, even 0.15 per cent has very little effect, if any, on the strength of the metal. In the experiments conducted by Mr. Wood the presence of 0.16 per cent sulphur did not appear to be harmful.

In Mr. Johnson's trials the only direct effect appeared to be that of making a closer grain, and consequently a stronger casting. Its effect, however, indirectly is undoubted, for unless the silicon is fairly high it prevents the separation of graphite, and a hard iron is the result. It follows, therefore, that when making the strongest iron castings the silicon should be low and the sulphur very low. The good quality of cold-blast iron is undoubtedly due chiefly to the association of a low silicon and sulphur content.

Chemical examination has shown that when the manganese reaches or exceeds 0.50 per cent the sulphur exists mainly as sulphide of manganese. This separates out before the metal becomes solid, and owing to its low specific gravity, begins to float upwards, and some of it eventually escapes out of the metal, but if the surface metal solidifies in advance, the elimination of the sulphide of manganese cannot occur, and it is mechanically held in the upper layer of metal. This is the reason why pigs contain more sulphur at the top than at the bottom.

Once the sulphide of manganese has separated independ-

ently it no longer exerts any influence on the carbon condition, even although it may be enclosed in the metal. In proof of this I possess a piece of a large gray cast iron, broken from the upper end of an ingot mold, which contains 1 per cent sulphur as sulphide of manganese, and yet there is no combined carbon present. The original metal contained about 0.90 per cent manganese, and 0.07 per cent sulphur.

Mr. Andrew Blair, of Boston, U. S. A., found sulphide of titanium in very gray pig iron in the form of idiomorphic crystals, which had the following composition:

Titanium	62.82%
Iron	1.82
Carbon	9.82
Sulphur	22.64
	97.10%

When little manganese is present, some of the sulphur most probably exists in the form of iron sulphide.

There can be no doubt that whether it exists as sulphide of iron or sulphide of manganese, each substance has the physical properties of scoria, and the presence of scoria from the purely mechanical point of view cannot be regarded as beneficial.

It will be observed on examining the specifications of the American founders that sulphur above 0.085 per cent is not allowed in anything excepting special hard iron such as that required for brake shoes, etc.

Whilst admitting the advisability of using irons with as low sulphur as possible for the strongest small castings, yet in larger sections and masses there can be no doubt that sulphur may be higher without great disadvantage; indeed, the best Staffordshire chilled rolls contain 0.17 per cent sulphur.

Effect of Carbon. — The combined carbon is mainly the determining factor of the hardness and shrinkage of a casting. The conclusions of Professor Howe, that the strongest iron is that in which the metallic matrix is pearlite with no massive carbide of iron, appears to me to be perfectly sound, but that excepting in the case where there is little or no phosphorus there is almost always some massive carbide present if the combined carbon reaches 0.90 per cent, for the simple reason that, as in Cleveland iron, the phosphorus unites with a considerable pro-

portion of the iron which, separating out as a eutectic, leaves less free iron capable of existing in the eutectoid pearlite. Probably 0.70 per cent is the highest amount admissible for such iron with good machining properties.

For general engineering, foundry castings about 0.50 per cent is a fair amount. (See Appendix I.)

The total carbon should not exceed 3.25 per cent either in soft or hard castings.

In the average irons available in this district it runs between 3.30 per cent and 4.20 per cent, the higher figure representing that in low silicon gray hematites.

Professor Howe considers air-furnace melting preferable to cupola melting on account of some of the carbon being burned out in the air furnace, but the same object can be gained by the judicious use of steel scrap in the cupola furnace. Bessemer steel scrap when melted alone in a very hot cupola absorbs about 3 per cent carbon, but, if melted with pig iron high in carbon, little carbon passes into it. Indeed, when melting 80 per cent pig with 3.75 per cent carbon, and 20 per cent scrap with 0.35 per cent carbon, the melted iron will contain about 3.25 per cent carbon. That is to say, the steel only absorbs under such conditions about 0.75 per cent carbon.

The quality of steel admissible must depend upon the other elements present in the iron, and on the size of the casting. To put a large dose of steel into a metal low in silicon and carbon and high in sulphur would make the iron white, but when the iron is sufficiently high in silicon and low in sulphur a large quantity of steel can be employed.

The conditions favorable for the use of steel can only be determined by the assistance of chemical analyses of the pig irons which have to be melted with it.

The reason why high carbon in the graphitic state is objectionable, is on account of the fact that every plate of graphite mechanically breaks the continuity of the metallic matrix, and the fewer of such breaks, within reasonable limits, the more coherent is the mass.

The great value of steel scrap has been fully proved by many founders in America, and also in some works in our own country.

Effect of Manganese. — The manganese in English and Scotch irons is generally higher than in those of American origin.

Founders in this country have always regarded Scotch brands as the very best obtainable, and these are peculiar by containing much higher manganese than allowed by American founders. In my own experience manganese strengthens the iron and, if it does not exceed 1.20 per cent, may be advantageous; indeed, it appears to effect the removal of a small quantity of sulphur or prevents that element from being retained from the coke in the cupola.

The experience in America, however, proves that good castings of high quality may contain very little, and it is questionable whether or not a slight increase in the combined carbon will not be equivalent to a decrease in the manganese.

Effect of Phosphorus. — The phosphorus exists in pig iron in the form of phosphide of iron (Fe_3P). It separates out and is the last to freeze when iron containing it solidifies. The actual amount corresponding to

0.5% Phosphorus	3.22% (Fe_3P)
1.0 ,,	6.45
1.5 ,,	9.67

This phosphide forms a fusible complex eutectic with a portion of the iron and its associated silicon and carbon in the cast iron. Its composition varies with the analysis of the iron. When partially solidified iron is compressed, this eutectic, associated with some of the iron, can be squeezed out of it. On treating Cleveland gray pig in this way I succeeded in obtaining a fusible mixture containing above 5 per cent phosphorus.

The microscope shows that this eutectic exists in isolated patches, embedded in the center of the masses of metallic matrix, which latter are bounded by the sheets of graphite. They rarely, if ever, join together or form continuous bands, and, as a rule, do not come in contact with the graphite plates. This eutectic is hard and brittle but not so hard as carbide of iron. When in a separate and massive state it is too hard to drill, but can be crushed to a powder in a steel mortar.

As the phosphorus increases, the relative mass of eutectic also proportionately increases. When 2 per cent is present the phosphide is nearly 20 per cent, and the separate particles sometimes join together to form lines or planes of weakness. As a consequence such metal is very tender. In proportion to

the increase of phosphorus the metallic matrix becomes weaker and weaker, the plane of fracture becomes more even and the iron does not tear in breaking but snaps suddenly.

The closer the grain of gray iron the greater the number of the isolated particles of the phosphide eutectic.

Phosphorus does not have any influence on the carbon condition unless the quantity is very great, when it appears to favor some of the carbon existing in the combined condition.

It does not appear to influence the chill, excepting perhaps to make a defined, sharp division between the chilled and unchilled portions.

It is believed to decrease the shrinkage, but it is probable that although test bars do apparently indicate that such is the case, the apparent non-shrinkage in a longitudinal direction may be more than compensated for by shrinkage in other directions, due to the peculiar plastic character phosphorus gives to iron below the point of primary solidification. More research is required in this direction.

Practical Suggestions. — To those who wish for the introduction of scientific methods into their foundries, the following points should be remembered:

1. An analyst who has no metallurgical knowledge is only useful for supplying true analyses, but in that respect he is indispensable.

2. Foundries rarely have fully trained metallurgists to control the mixing and casting of metals.

3. If there is a metallurgist in the foundry he will be able to usefully apply the analyses provided by the analyst.

4. The primary essential is to have accurate analyses, and in making a selection a chemist should be chosen who has had a metallurgical training in a technical college, or a full course of City and Guilds, or other equally good series of lectures on the metallurgy of iron and steel, or who, by private study, has fully qualified himself.

5. It is a rare thing to find a chemist who has had practical experience in a foundry, and the founder must take the material available.

6. Having selected a man, his real training must begin on entering the foundry laboratory, and whether or not he devel-

ops into a useful metallurgist must largely depend upon his ability and capacity for gaining knowledge.

7. To facilitate this his employers should provide him with every standard metallurgical treatise containing useful data on foundry practice, a complete set of the journals of the Iron and Steel Institute and kindred institutions, the "Foundry Trade Journal," "The Iron and Coal Trades Review," "Engineer," "Engineering," other English technical papers, also "The Iron and Steel Magazine," edited by Mr. Sauveur, Boston, U. S. A., and in order that he may obtain the transactions of the American Foundrymen's Association, he should become a member of that institution. He should also be supplied with the valuable index, *viz.*, "The Engineering Press Monthly Index Review," and whenever any paper of value on foundry practice is published it should be obtained. The index referred to will enable him to find out where and how he can obtain them. If there is objection on account of the cost of this course, efforts should be made that books and papers become available at the nearest free library.

8. One of his duties should be to read everything published on foundry work, and to insure that he does this he should supply periodically to the head or principal a review of the publications.

9. He should ascertain the best chemical composition for any particular class of work, and castings which have given maximum good service should be obtained and analyzed. All castings which have gained a high reputation should be tested, and portions of castings which have failed should likewise be analyzed. In this way real knowledge will be obtained, and a solid foundation laid, for he will know what to aim at and what to avoid.

10. It may be accepted as a general rule that the value of any average brand depends upon its composition; that is to say, if a mixture of several brands has the same composition as that of any other brand, the metal will have the mechanical properties of that brand. For instance, it is easy to make a mixture from irons in this district which will have all the good properties of any of the Scotch brands.

11. If the output of a foundry does not justify the employment of a metallurgical analyst, the makers of pig iron should be asked to provide analyses with each delivery to an approximate specification, and if an extra price is demanded for this,

say sixpence to a shilling per ton, it should be paid — they will be worth it.

12. Some owners of foundries have informed me that they would have great difficulty in introducing analytical control into their works owing to the prejudices of the foremen. Of the foremen who hold such prejudices it may be said that they are working with their left hand only. If they, themselves, would demand analyses they would then be able to work with their right hand also. An analytical metallurgist in their works would be found as valuable in the conduct of the establishment as the secretary, accountant or the timekeeper.

Concluding Remarks. — In the preceding pages, and in the appendices, I have sought to bring to a focus the experience of those who have applied their attention to the application of science to cast-iron foundry practice, and have endeavored to outline a system for those who have not as yet seen the necessity for working on scientific lines, but who, in the natural order of things, will eventually find it to their advantage to do so. I have, however, just touched on the fringe of the subject. The influence of correct casting temperature on the properties of the iron, the management of the cupola and air furnaces, the best composition for molding sand, etc., have not been discussed, but in these directions science can be and has been brought to bear.

I can now fittingly close my remarks by quoting a statement made by Mr. Moldenke, in a paper on the "Physics of Cast Iron," read before the American Institution of Mining Engineers, in February, 1904, who says: "The American founder had come to realize that the chemical specification alone was the best safeguard," and that "in dollars and cents, the benefit of science to the much neglected foundry industry in America has been incalculable."

APPENDIX I

Various Authorities on the Effect of Metalloids, etc., in Cast Iron

William J. Keep, in his work on cast iron, which is a record of original research, containing much valuable matter, appears to form the following conclusions with regard to the effect of elements upon cast iron.

Silicon hardens cast iron, but its effect of throwing the carbon out of combination is to soften the metal. The more completely this change is effected the softer will be the iron, provided the silicon does not exceed 3 per cent. It increases the strength up to 3 per cent in ½-inch bars. The lower the silicon in thin castings the weaker the metal, whilst the reverse is the case in large castings.

Silicon removes the chilling tendency in iron. It increases the fluidity. It reduces shrinkage by changing the combined carbon into graphite.

The shrinkage decreases as the size of the casting increases.

He says: " The founder must be made to realize that it is not the percentage of what is in his iron which is of use to him, but it is the influence exerted by that which is in the cast iron that affects the physical quality."

Phosphorus, if anything, hardens cast iron, reduces the shrinkage, and has no influence on the chill. In any proportion it weakens iron, but has the valuable property of making the iron more easily melted. It has no influence upon the grain of the iron, and does not have any influence on the carbon condition. He says that 1 per cent is a reasonable quantity for general foundry work, but that American irons rarely contain so much.

Sulphur tends to harden iron. Gray pig rarely contains more than 0.10 per cent sulphur.

His experiments show that 0.05 per cent will not exert any appreciable influence, and what little is done is at once corrected if the silicon is slightly increased. He thinks he has shown that the average foundryman's ideas about sulphur are partly superstitious.

Manganese does not materially influence the chill, and what is usually found in foundry irons has no influence on the strength.

One per cent does, however, increase the hardness, independently of the carbon condition. He does not appear to consider that there is any advantage in the use of manganese.

Professor Turner, in his published lectures on "Iron Founding," when discussing the important rôle played by combined carbon, says that for maximum tensile and transverse strength this should be 0.47 per cent, whilst for the highest crushing strength it should be over 1 per cent. In referring to the effect of sulphur, briefly stated he says that its effect is to counteract that of silicon, and that one part of sulphur will counteract the effect of ten parts of silicon. He suggests that for soft castings the sulphur should not exceed 0.03 per cent or 0.04 per cent., and in strong metal, 0.07 per cent.

He suggests 0.5 per cent of phosphorus as the amount suitable for strong castings of good quality, but for ordinary practice, where soundness and fluidity are of more importance than strength, from 1 to 1.5 per cent may be present.

With regard to manganese Professor Turner says that ferro-manganese may be used for special purposes as a softener, particularly with sulphurous irons.

Professor Howe and Professor Sauveur very correctly regard pure cast iron as a metallic matrix cut up mechanically by plates of graphite. In very soft iron the matrix is ferrite. In steels of maximum strength the matrix may be regarded as pearlite with about 1 per cent carbon cut up by graphite plates.

Graphite weakens iron; therefore, if the carbon is partly combined, — under 1 per cent, — there will be about 1 per cent less as graphite, and the cast iron should on that account be stronger than one containing all the carbon as graphite.

Provided the matrix contains no massive cementite, and is all pearlite, it should have a maximum strength, for pearlite is the strongest constituent of carbon steels.

Mr. Keep appears to have a different opinion, for he considers that combined carbon has no influence excepting to weaken cast iron. Probably this gentleman based his judgment on the effect of massive carbide and not of the fine plates of carbide in pearlite.

Professor Howe considers air-furnace melting superior to cupola melting on account of the decarburization which occurs in the air furnace first, and which is unusual in the latter.

Mr. Guy Johnson, Embreville, Tenn., in a paper read before the Iron and Steel Institute in 1898, on the action of metalloids on cast iron, gives a large number of correlated chemical and mechanical tests of Embreville iron, from which the following approximate conclusions may be drawn:

1. The effect of combined carbon.

Analysis of Iron

	Very open	Very close gray
Silicon	1.20%	1.29%
Sulphur	0.06	0.05
Phosphorus	0.17	0.18
Graphite	3.72	2.84
Combined carbon	0.12	0.92
Tenacity, tons square inch	7.8	16.0
Transverse breaking stress	1,750 pounds	2,950 pounds
Deflection	9-32 inch	19-32 inch

Effect of 0.8 per cent combined carbon on the tenacity, increase = 8.2 tons.

Effect of 0.1 per cent combined carbon on the tenacity, increase = 1.00 tons.

Effect of Phosphorus

	Gray	Light gray
Silicon	1.09%	1.07%
Sulphur	0.08	0.08
Phosphorus	0.12	0.55
Graphite	3.03	2.83
Combined carbon	0.78	0.81
Tenacity, tons square inch	11.40 tons	9.2 tons
Transverse breaking stress	2,650 pounds	2,150 pounds
Deflection	16-32 inch	9-32 inch

Effect of 0.43 per cent phosphorus on tenacity, decrease = 2.2 tons per square inch.

Effect of 0.10 per cent phosphorus on tenacity, decrease = 0.51 tons per square inch.

Effect of Silicon

	Gray	Gray
Silicon	0.31%	1.76%
Sulphur	0.07	0.07
Phosphorus	0.18	0.18
Graphite	3.03	3.07
Combined carbon	0.79	0.83
Tenacity, tons square inch	14.10 tons	10 tons
Transverse breaking stress	2,300 pounds	2,650 pounds
Deflection	10-32 inch	15-32 inch

Effect of 1.45 per cent silicon on tenacity, decrease = 4.1 tons per square inch.

The decrease was not proportional per unit of silicon. For instance, 1.27 per cent silicon in a pig iron gave a tenacity of 12.5 tons, 1 per cent having reduced it by only 1.6 tons.

Effect of Sulphur

	Gray	Close gray
Silicon	1.22%	1.26%
Sulphur	0.05	0.17
Phosphorus	0.20	0.21
Graphite	2.98	2.99
Combined carbon	0.83	0.92
Tenacity, tons square inch	11.2 tons	14.8 tons
Transverse breaking stress	3,000 pounds	2,960 pounds
Deflection	18-32 inch	13-32 inch

Apparent effect of 0.12 per cent sulphur on tenacity, increase = 3.6 tons.

It is evident that the increase in strength is not due to any direct beneficial effect of sulphur, but to its influence in making a much closer grained iron.

Drop Tests

Silicon	No. of blows
0.53%	8
1.01	10
1.50	8
2.03	3
3.11	Broke.

Above 1.5 per cent silicon rapidly reduces resistance to sudden shock.

Phosphorus	No. of blows
0.15%	11
0.30	8
0.40	3
0.52	1

More than 0.30 per cent rapidly reduces resistance.

Sulphur	No. of blows to break
0.07%	10
0.14	8
0.17	8

Sulphur has little effect upon the resistance of the metal to shock.

Chill Tests

Chill pieces, 1 × 2 × 20 inches.

Silicon	Depth of chill
1.76%	No chill.
1.55	Perceptible at edge.
1.27	⅛ thick.
1.07	¼ thick.
0.88	⅜ thick.
0.31	Entirely chilled.

Phosphorus had no effect in producing variations in the depth of the chill, but the chill on the iron with 0.18 per cent phosphorus extended into the gray by fibers, whilst 0.875 per cent gave a chill sharply separated from the gray portion.

Effect of Melting in Cupola

Mr. Johnson gives 15 tests, showing the effect ot melting iron in the cupola.

It would appear that the silicon was reduced between 0.15 per cent and 0.30 per cent by melting, and the sulphur increased by about 0.04 per cent.

DRY AIR IN THE BLAST FURNACE

In view of the importance of Mr. Gayley's experiments for drying the air before its introduction into the blast furnace and of the intense interest taken in the results he has published, we reproduce here the comments which have appeared in responsible technical papers during the month of February, 1905. We solicit correspondence on the subject from our readers. — Ed.

"Iron and Coal Trades Review," February 3, 1905.—Referring to Mr. Gayley's now historic paper on the subject of dried air for blast-furnace work, Mr. B. Osann, in a recent issue of "Stahl und Eisen," expresses doubt whether the process will, in practice, prove as valuable as its inventor believes. The figures cited by Mr. Gayley are, he says, contradicted by practical experience, even during the most protracted cold seasons. If they were accurate it might be desirable to transfer the pig-iron industry to more northern climates, perhaps even to the district where the Kiirunavara and Gellivara ore deposits occur; but for the present smelters will do well to wait more extended reports on the new system than are now available, since Mr. Gayley admits there is a possibility of many of the values being modified by longer experience. The two sets of experiments already made lasted

only a fortnight each, and, therefore, their results must be taken with caution, more especially since Mr. Gayley's explanation — that the advantages obtained were solely due to the uniformity of the moisture content of the air — is unsatisfactory. Far greater irregularities in results may be caused by variations in the composition and moisture content of the ore and coke, to say nothing of fluctuations in the temperature of the blast, especially in the case of defective heaters. Every iron maker is aware of the fluctuations in the coke consumption of a blast furnace, and knows that a furnace which has been kept hot for some time can stand a reduction in the coke supply, considerably below the mean, particularly when pig iron with less than 1 per cent of silicon is in question, and also under special conditions. That in these circumstances a continuous consumption of 77.7 per cent of coke (calculated on the output of pig iron) is simply impossible will be evident from a consideration of the heat values involved.

Taking this percentage as a basis, the number of calories required for producing one ton of pig iron would be:

	Cal.
Heat of reduction	1,790,050
Smelting slag	217,600
Smelting the iron	250,000
Expelling carbon dioxide	198,970
Expelling moisture	152,780
Total	2,609,400

However, from the calories consumed by the heat of reduction of the iron in the charge, a certain deduction must be made on account of the reduction caused by the oxidation of the carbon monoxide to carbon dioxide. As a result there remain 1,590,000 calories, but this must be increased by at least 30 per cent to compensate for loss of heat in the furnace gases, cooling water and radiation, so that the figures become 2,067,000 calories. Since each pound of carbon consumed liberates about 1,380 calories, when the blast temperature is 450° C., the proportion of carbon to iron will need to be 68.3 per cent, plus 3.5 per cent taken up by the iron, or 71.8 per cent in all, which corresponds to 83.5 per cent of coke. Even this percentage is below the yearly average (88 per cent) consumption at the ten furnaces of the Edgar Thomson works at Pittsburg.

Drying the air by means of refrigerating machines would reduce the consumption of heat by 81,490 calories, since the volume of air by the 68.3 per cent of carbon aforesaid (151.36 pounds) is 9,924 cubic feet, and as the amount of coke consumed in eliminating the moisture from that volume of air is 6.88 pounds or 3.13 per cent of the iron in the charge, the coke consumption would be lowered to 80.4 per cent, which, nevertheless, is higher than the 77.7 per cent mentioned by Mr. Gayley. On referring these figures to the original coke charge at the Isabella furnace, namely, 96.6 per cent, the saving would be slightly under 4 per cent, in place of the assumed 20 per cent, and no larger than would be secured by raising the blast temperature about 90° C. Taking into consideration the increased combustion temperature in the furnace, Mr. Osann shows by a series of calculations that increasing the temperature of the blast by 140° C. will produce the same saving of coke as is effected by drying the air. In his opinion the furnace in which the Gayley experiments were made must have been an unsatisfactory one, and the advantage accruing from the introduction of the refrigerator must have been due to the possibility afforded of increasing the amount of air forced in by the blast. The probability of this assumption is strengthened, he thinks, by the circumstance that the loss in dust was diminished from 5 per cent to 1 per cent, and by the relatively small output per diem, the average being only 364 tons, whereas the Edgar Thomson furnaces, of slightly greater cubical capacity, turn out over 500 tons. The increase of the output to 454 tons by the introduction of the refrigerator is nothing remarkable when it is considered that at the works in question the maximum daily output is 834 tons, with 634 tons as the highest daily average for one month (May, a time when the moisture content of the air is not inconsiderable). Again, before the refrigerator was used, the speed of the blast fans was 13 per cent lower than those used at the Edgar Thomson works, though the furnace was only 4 per cent smaller. Hence, the circumstance that the efficiency of the blower was raised by 11 per cent without increasing the consumption of steam indicates that it was only at this time that normal conditions were established in the furnace, and the latter began to work properly. It had become thoroughly heated owing to the high coke consumption, and probably well incrusted with coal

dust on account of the slow working, so that no disadvantage was incurred by reducing the percentage of coke, the furnace existing, as it were, on the accumulated store of internal material. That such accumulations of deposited carbon do exist is well known, and, indeed, this deposition is increased by the splitting up of two molecules of carbon monoxide into one of carbon dioxide and one of carbon; so that when the furnace is worked at a slow rate, considerable disturbances are produced by this cause.

Turning now to the increased efficiency of the blower, it follows that any saving in coke consumption is attended with a corresponding economy of air, irrespective of the efficiency of the machine, and Mr. Gayley seems to have made the mistake of referring the volume of air to the tonnage of pig iron produced, and attributing the entire saving to the refrigerator, whereas, logically, it should be apportioned between this and the saving in coke. This can be demonstrated by calculating the work of compression with different percentages of moisture, referred to a given quantity of oxygen supplied to the furnace. For this purpose, Mr. Gayley's figures, namely 5.3 grains per cubic foot, may be accepted as the mean quantity of moisture in the air during the summer months, so that the increase produced in the weight of the air by the use of the refrigerator may be considered to average 11 per cent. Moreover, a slight increase of power (about 0.14 per cent) is needed to compress the dried air. In considering the work done by the blowing engine, it must be remembered that the combustion of each one pound of carbon in the furnace will consume about 64½ cubic feet of air; and since 2,120 pounds of coke (86 per cent carbon) are needed per ton of pig iron, 77 pounds of which are taken up by the iron, the residual 2,043 pounds of coke will require some 112,000 cubic feet of air. The output of the furnace being 364 tons of iron per diem, the volume of air to be supplied by the blowers will be a little over 472 cubic feet per second. However, it is found by experience that an addition of 50 per cent must be allowed to counteract the effect of higher air temperature and diminished pressure, the influence of the clearances and loss by leakage in the cylinders, pipes and heaters, so that the volume of air actually needed will be 706 cubic feet per second, a quantity furnished, plus a small margin, by the engines men-

tioned by Mr. Gayley when run at the specified speed of 114 revolutions per minute. Under these conditions the engines will develop a force of 2,515 horse-power (theoretically). To ascertain the actual work done, these figures must be increased by 1.1 per cent for the force consumed in lifting the valves, and 3.8 per cent for compensating the vacuum produced by the suction stroke, together, 4.9 per cent; and, on the other hand, a deduction must be made of 6.3 per cent for the surplus resulting from the difference between the adiabatic and the true compression, and 1.1 per cent for the work done by the compressed air left behind in the clearances, together, 7.4 per cent, *i.e.*, a net deduction of 2.5 per cent. Consequently the actual indicated power developed by the engine is 2,452 horse-power at the compressor cylinder. This being 87.6 per cent of the power developed at the steam cylinder, the value for the latter will, therefore, be 2,800 indicated horse-power, which agrees fairly well with the 2,700 horse-power mentioned by Mr. Gayley, so that the mean of 2,750 horse-power may be taken for further calculations. Now, as already mentioned, the weight of the dry air is about 11 per cent higher than that before drying; and there is an additional saving of 4 per cent in the volume of air otherwise consumed by the extra coke needed to generate the blast for decomposing the moisture in the blast air; so that there will be an excess of about 15 per cent of steam, *i.e.*, 412 horse-power hours, available for other purposes, as well as about 80 pounds of coke per ton of pig iron, both of which may be withdrawn without affecting the work of the furnace. Against this, however, must be set the cost of the refrigerating plant, which will amount to a capital expenditure of about £25,000 (as a matter of fact, the plant referred to by Mr. Gayley is stated to have cost this sum — $125,000 — without boilers).

In expressing the results of his calculations in money value, the author assumes the price of coke at Pittsburg to be 8*s*. per ton, but also takes two other values, 14*s*. and 23*s*. per ton, applicable to other local conditions. Without allowing anything for the steam-raising power of the blast-furnace gas, which is assumed to be already fully utilized, he works out the cost of developing 1,000 indicated horse-power hours at 5.15, 10.13, and 16.77 shillings respectively. The saving effected by the use of the refrigerating plant is calculated to be 0.55, 0.89 and 1.40

shillings respectively, and the increased expense due to the use of refrigerating plant, 0.66, 0.83 and 1.07 shillings in the three cases. That is to say, with coke at 8*s*. per ton, the refrigerating plant will increase the cost of the pig iron by 0.11*s*. per ton, whereas with the dearer coke there will be a slight saving of 0.06 and 0.33 shilling per ton respectively. The contingency of high coke rates is, however, considered too remote to justify the erection of an extensive refrigerating plant, since the advantages mentioned might easily be entirely nullified by difficulties in obtaining a supply of cooling water. Mr. Gayley made his calculations differently, since he put a saving of 20 per cent of coke to the credit of the refrigerating machine, whereas in the foregoing the saving is given as only 4 per cent in order to harmonize with known scientific and practical results. Even where the advantages secured by drying the blast are due to defective working of the blowing engines, it will be found more economical to put in new engines than to install a refrigerator, for, though the prime cost of the two installations is about the same, the advantages produced by the refrigerator can be equaled if the new engine economizes merely 2¼ pounds of steam per horse-power hour. Other means, by the aid of which the same advantages might be secured at less cost, are the installation of blast-furnace gas engines, the employment of higher blast temperatures and the use of an efficient method of gas purifying. It must also be remembered that with undried air the whole of the heat generated by the combustion of the hydrogen liberated from the moisture is recovered in the gases, the loss in this respect being about 3 per cent of the total heating value. For special purposes, however, the use of refrigerating plant for drying the blast may find justification, *e. g.*, when the question is one of producing a certain iron alloy at a very high furnace temperature, regardless of cost; though even in such cases it is improbable that the high-blast temperatures now attainable would be insufficient.

"The Engineer" (London), February 17, 1905. — The correspondence on this subject is becoming so voluminous that the reader is tempted to look at the end of such an interesting and argumentative letter as that of Mr Elbers to ascertain the conclusions arrived at before reading it through, and such an investigation conveys the impression that Mr Gayley has only revived

an old-fashioned theory of Neilson's — not Neilsen — which has been a steady block to progress ever since A more systematic perusal, however, seems to show that, although the writer believes that the cooling effect of dissociation of water vapor in the blast is more efficacious in protecting the brickwork of the furnace from fusion than water jackets, he doubts whether increase of moisture in the blast is perceptible at the tuyères, and that variations in stove heat are mainly caused by water evaporated from the materials of the charge. In view of these contradictory utterances, a consideration of the arithmetic of the subject, as contained in the annexed table, may be of use. It is based on the following conclusions:

1. Carbon may at appreciable initial temperatures be oxidized either by air or water vapor, with a similar heat development by oxidation of 2,470 centigrade heat units per unit of carbon, the whole of which is available in the former case, but in the latter, where a preliminary expenditure of 4,800 units is necessary for freezing the oxygen, the result is a negative balance of 2,330 heat units per unit of carbon.

2. The unit of air gasifies 0.176 carbon, producing $\frac{3}{17} \times$ 2,470, or 436 heat units, and the unit of water vapor 0.667 carbon absorbing $\frac{2}{3} \times$ 2,330, or 1,553 heat units, after allowing for the heat developed by the formation of carbonic oxide.

Oxidizing agent		Heat developed cals.	Weight of gas produced	Specific heat of gas		Theoretical temperature, centigrade
Air	Water	Air + Water − Net +		Per unit	Total	
1.00	0.00	436 — 0 = 436	1.176	0.245	0.288	1510
0.99	0.01	432 — 16 = 416	1.181	0.247	0.292	1425
0.98	0.02	427 — 31 = 396	1.186	0.249	0.295	1342
0.97	0.03	423 — 47 = 376	1.191	0.251	0.299	1258
0.96	0.04	419 — 62 = 357	1.196	0.253	0.303	1178
0.95	0.05	414 — 78 = 336	1.201	0.255	0.306	1098
0.94	0.06	409 — 93 = 316	1.206	0.257	0.310	1019
0.93	0.07	405 — 109 = 296	1.211	0.259	0.314	946
0.92	0.08	401 — 124 = 277	1.216	0.261	0.317	874
0.91	0.09	397 — 140 = 257	1.221	0.264	0.322	800
0.90	0.10	392 — 155 = 237	1.226	0.266	0.326	727

Taking the figures for dry air as 100, the relative proportions of fuel consumed and heat developed are as follows:

Air : Water	100:0	99:1	98:2	97:3	96:4	95:5	94:6	93:7	92:8	91:9	90:10
Carbon oxidized . . .	100	103	106	109	111	114	116	119	122	125	128
Available heat developed	100	95	91	86	82	77	72	68	63	59	54
Temperature realized . .	1570	1425	1342	1258	1178	1098	1019	946	874	800	727

Although the table goes far beyond the possibilities of the blast furnace, it reproduces the conditions of the gas producer, where water vapor is injected with the air to reduce the initial heat of the gas formed, which would otherwise be delivered at a uselessly high temperature, the heat so absorbed being utilized in gasifying more carbon, to give a richer fuel gas at the place of consumption. These conditions seem to be satisfied with 5 to 7 per cent of water, which can be supplied continuously without cooling the producer below the point necessary to keep the fuel active in reducing carbon dioxide, but with a higher proportion the latter gas increases, and ultimately steam passes through unchanged, these latter conditions being exemplified in the Mond producer. In all cases, however, it will be seen that with increase of water in the air the temperature falls, while the carbon consumption increases, which, of course, is proper in a gas producer, but very much the reverse in a blast furnace, the cooling effect being developed at the place where the maximum heat is required. The effect of 1 per cent of water seems to be an increase of 3 per cent in carbon consumption and a diminution of 5 per cent in the heat developed, as compared with dry air. To restore this missing heat about 100° of stove heat would be necessary, so that, roughly speaking, 1 per cent of water vapor and 100° of heat in the blast may be taken as about equivalent, and such a variation would be quite appreciable in the working of a heavily burdened furnace.

In comparing the heat absorption caused by the drying of wet ore with that due to dissociation of water vapor in the blast, the relative scale of the two operations must be considered. With a 60 per cent ore, with 10 per cent of water, the quantity of the latter contained in the amount necessary to produce a unit of metal is 0.16, while in the corresponding quantity of air, with 1 per cent of moisture, it is 0.06. To evaporate the former 86 heat units are required, while the conversion of the latter into water gas takes 93 units. The evaporation, however, is, or

ought to be, done by gas that has exhausted its reducing energy, while the decomposition of water abstracts heat from the hearth, where it is wanted, for no particularly useful purpose elsewhere.

G. T. Harrap, "The Engineer" (London), February 17, 1905.— Having noticed the abstract of a paper read by Mr. Gayley in New York on "Dry Air in the Blast Furnace," which appeared in your issue of November 18, 1904, together with the leading articles of the same date, and January 20, 1905, it appears that the matter requires further consideration.

I have not the complete report before me, but taking the figures given in the abstract and leading article, the paper can hardly be considered as a perfect record of what actually occurred. For instance, it is stated that during a certain period "the average moisture in the atmosphere was 5.66 grains per cubic foot, and in the dried air 1.75 grains," *i. e.*, a reduction of 3.91 grains per cubic foot; also that "69 pounds of water were removed from the blast per ton of iron produced, which represents an average of 23,192 pounds per 24 hours." Elsewhere it is stated that the average daily output of iron was 452 tons.

Now, 69 pounds of water per ton of iron for 452 tons equals 31,188 pounds per 24 hours Again, a reduction of 3.91 grains of moisture per cubic foot in 34,000 cubic feet of air per minute amounts to 27,417 pounds of water per 24 hours. The average temperature of the cooled air was apparently about 20° to 22° F. At these temperatures air would be saturated when containing 1.287 grains and 1.414 grains of moisture respectively, as against the average figure of 1.75 grains mentioned in the paper; further, it is known that even when cooled the air could not remain saturated; consequently these figures would be still further reduced.

In connection with the moisture question it might also be pointed out that there appears to be a slip in the first table given in the abstract, showing gallons of water entering per hour into a furnace using 40,000 cubic feet of air per minute at various temperatures and humidities. The figures given in the gallons of water column are based on the assumption that one United States gallon weighs 8.55 pounds, whereas it is usually considered to be 8.33 pounds. For instance, at 73.6° C., 5.16 grains water per cubic foot, the number of gallons is given 206.4, whereas it

should be 212.4 gallons — an error sufficient to disturb any calculation dealing in large numbers.

Your explanation of how the saving in coke has been brought about requires further elucidation, for you say: "The chilling of the air augmented its density, and virtually increased the delivery of the blast engines, while the pressure, and consequently the work done, remained unaltered," and in a later paragraph in the same article, "With dried blast 96 revolutions per minute of the blowing engines burned nearly 1 per cent more coke, and produced 89 tons more pig iron in 24 hours than 114 revolutions on natural air."

Assuming the figures you have given as being correct, I find the weight of air delivered to the blast furnace per minute before and after cooling as follows:

Before drying. — 40,000 cubic feet per minute at 70° F.
Volume per pound, 13.342 cubic feet.
Weight of air per minute, 2,998 pounds.
After drying. — 34,000 cubic feet per minute at 20° F.
Volume per pound, 12.08 cubic feet.
Weight of air per minute, 2,814 pounds.

i. e., the saving in fuel was effected when actually a less weight of air was being delivered to the furnace.

Referring to the figures you have given as volumes per pound at different temperatures, it should, however, be pointed out that these figures refer to dry air. For instance, air at 70° F., containing 7.98 grains of moisture per cubic foot — saturation point — has a volume of 13.468 cubic feet per pound. From the gross weight obtained by using this latter figure must then be deducted the weight of the moisture contained in the air. Calculating in this manner, 40,000 cubic feet of air at 70° F. saturated with moisture contains 2,924 pounds of air, or with 5.66 grains of moisture per cubic foot the net weight of the air would be approximately 2,946 pounds.

Similarly, for 34,000 cubic feet of air at 20° F. containing 1.287 grains of moisture per cubic foot (saturation point), the air would weigh approximately 2,804 pounds. Using net weights of air obtained above, and assuming the fuel consumption as stated in the paper to be correct, it will be found that, before drying, 5.5 pounds of air were consumed per pound of coke; after drying, 5.17 pounds of air were consumed per pound

of coke; or a reduction in air consumed per pound of coke of 6 per cent.

With regard to the water entering the furnace with the ore and coke, there can be no question but that this water is vaporized and carried away with the waste gases long before the materials originally containing the water drop far enough down the furnace to reach the dissociation temperature.

The saving of fuel appears to me to be due to (1) greatly decreased dissociation of water by removal of moisture from air; (2) increased thermo-chemical efficiency, as shown by the analysis of the waste gases; (3) less weight of air to be heated in the furnace.

As regards (1), assuming that the moisture is removed from the air at the rate of 3.91 grains per cubic foot for 40,000 cubic feet per minute, it can be shown that the heat required for the dissociation of this moisture per pound of coke consumed amounts to approximately 250 B T.U.'s. The saving in fuel which this represents obviously depends on the efficiency with which the fuel is consumed, and the fact that the dissociation takes place in the critical portion of the furnace.

It is difficult to calculate the exact percentage of the saving, but, as a basis, take the coke as having a calorific value of 13,000 B.T.U.'s per pound, which, allowing for 5 per cent moisture by weight, becomes 12,350 B.T.U.'s. Sir. J. Lowthian Bell's estimate of the distribution of heat in a blast furnace indicates that, roughly, 50 per cent of the heating power of the fuel is undeveloped; further, that of the remainder about 50 per cent only is used in "chemical action in smelting." Assuming these figures to be approximately correct, the effective calorific value of 1 pound of coke becomes as follows:

	12,350 B.T.U.'s (as above)
Less 50%	6,175
	6,175
Less 50%	3,087.5
	3,087.5 B.T.U.'s

Looked at in this light a saving of 250 B.T.U.'s, therefore, becomes a saving of about 8 per cent in the weight of fuel required.

Doubtless, higher up in the furnace the dissociated oxygen and hydrogen would recombine partly or wholly, but the heat thus recovered could have but little effect on the fuel efficiency, although doubtless having an effect in the increased temperature of the waste gases, as observed by Mr. Gayley.

(2) A simple calculation based on the figures given for the analysis of the waste gases shows that about 11.4 per cent more heat was being obtained from the fuel after the application of the dried air, or, putting it the other way, shows a saving of 10 per cent in fuel.

(3) I have previously shown about 6 per cent less by weight of air per pound of coke was used with dried blast. As the heating up of this air is avoided, there is a further saving of about 2 per cent.

The total saving thus becomes:

(1)	8%
(2)	10
(3)	2
	20%

Without casting the least aspersion on Mr. Gayley's figures, with the exception of the few apparent discrepancies I have pointed out, I am confident that in this country and on the Continent, where more economical methods of working prevail, but few furnaces will show the saving indicated, and the results are more likely to be between 10 per cent and 15 per cent.

Although the idea of employing dried blast is not altogether new, Mr. Gayley is to be congratulated on the successful result of a tedious and costly experiment. That it was tedious is shown by the fact that his first United States and English patents were applied for in 1894, whilst the first notice, as far as I am aware, in this country announcing the installation of the plant at Pittsburg appeared in "Ice and Cold Storage" for July, 1901. That the experiment was costly will be readily admitted by those who are acquainted with the expense of installing a 450-ton refrigerating plant with its accessories,

Referring to the type of plant employed by Mr. Gayley, as described in the abstract of this paper, and in his numerous United States and English patents, it is evident that the apparatus is hardly such as would recommend itself to experienced

English refrigerating engineers. This is borne out by the number of patents relating to improved methods of drying air for blast furnaces which have recently been applied for in this country.

In connection with the refrigeration required for cooling air in bulk, an important point appears to have been somewhat lost sight of, *viz.*, that the moisture is contained in the atmosphere in the form of steam vapor, and not as water. In cooling air containing moisture from, say, 70° F. to 20° F. in one operation, as Mr. Gayley appears to do, it is evident that not only has heat to be taken from the air, but also that the latent heat of the steam vapor must be removed, and, further, the latent heat of the water to turn it into ice at 20° F. What this means is best illustrated by figures.

In cooling 34,000 cubic feet of air from 70° F. to 20° F., and at the same time removing, say, 4 grains of moisture per cubic foot in one operation, the heat to be removed is as follows:

From the air	29,750 B.T.U.'s
,, vapor to water at 32° F.	21,494
,, water at 32° F. to ice at 20° F.	2,871
	54,115 B.T.U.'s

When it is remembered that this amount of heat has to be removed per minute, that the plant must be in duplicate, and that the temperature and humidity of the air may be considerably greater than those I have assumed, the necessity for a large refrigerating plant becomes apparent.

The ironmasters of this country are hardly likely to expend the capital necessary for such a plant as described by Mr. Gayley, but as it is possible to reduce the amount of refrigeration required, by means of special arrangements, which also materially increase the efficiency of the plant, I consider that the cost of an installation may be reduced to about a half of what has been thought necessary. There would then be more likelihood of the system being tried, and another branch of the refrigerating industry inaugurated.

[Inasmuch as the least weight of air that will burn a pound of coke to CO is 6 pounds, it is clear that the further supply of oxygen required for complete combustion must be had from the ore. The least quantity of air that will burn a pound of coke

to CO_2 is 12 pounds. Our correspondent gives 5.17 pounds as the consumption of air per pound of coke. Assuming this to be true, and bearing in mind the enormous output of CO, we do not quite see how it can be possible that the calorific output of a pound of coke in the furnace can be 12,350 B.T.U., as stated by our correspondent. We have taken exception from the first to the words "dry air in the blast furnace." The proper phrase is "dry air in the Cowper stove." The work done there is persistently overlooked; why we vainly try to guess. — Editor, "The Engineer."]

H. B. Weaver, "The Iron Age," February 16, 1905. — The article in "The Iron Age" of February 9, "Some Foreign Opinions of the Gayley Dry Air Blast," leads me to express the opinion that the only saving that can be claimed by Mr. Gayley for his dry-air blast is the fuel saving, equal to the quantity of fuel required to dissipate the quantity of water removed, less the cost of power required to operate the device and the expense of installing and maintaining the plant.

The work of the furnace on which Mr. Gayley bases his claims for wonderful economies due to dry blast, in my opinion, shows very conclusively that the improvement was due to increasing the burden of ore and increasing the quantity of lime in the cinder, rather than to the use of dry air.

The burden on the furnace from August 1 to 11, while working on atmospheric air, was: coke, 10,200 pounds; ore, 20,000 pounds; stone, 5,000 pounds. If we assume that the fuel required 15 per cent of its weight in limestone to properly flux its ash, we find the duties of the stone are as follows: to flux ash in fuel, 1,530 pounds; to flux gangue in ore and stone, 3,470 pounds, or 17.35 per cent of the weight of the ore.

The burden on the furnace from August 25 to September 9 while working on dry blast, was: coke, 10,200 pounds; ore, 24,000 pounds; stone, 6,000 pounds. Assuming that the fuel still requires 1,530 pounds of the stone, we have 4,470 pounds of stone, or 18.62 per cent of the weight of the ore, an increase of 1.27 per cent of stone.

It is a well-known fact that by increasing the burden of ore on a furnace the temperature of the escaping gases is lowered, the quantity of fuel required to make a ton of ore is reduced, and

the yield of the furnace is increased. As the ore burden on a furnace is increased the quantity of blast per ton of iron decreases, for the simple reason that a greater proportion of the fuel is oxidized by the oxygen in the ore.

By increasing the quantity of lime in the cinder the temperature of the cinder is raised, thus raising the hearth temperature and increasing the power of the cinder for removing sulphur.

I think that had Mr. Gayley given this furnace the extra lime and ore with 300° or 400° higher blast temperature with atmospheric air, his results would have been just as satisfactory.

J. E. Johnson, Jr., "The Iron Age," February 16, 1905. — The paper of Mr. Gayley before the Iron and Steel Institute last autumn has created a stir among blast furnacemen the like of which has certainly not occurred for many years. To any one at all familiar with current technical literature it is evident that the surprise at the boldness of the conception and success in execution of Mr. Gayley's idea have been followed by amazement at the magnitude of the saving which resulted and the apparent disproportion between the quantity of moisture removed and the effect produced. This latter phase of the question is now engrossing the attention of some of the ablest minds in the profession, both in Europe and here, and several explanations have been put forward, none of which, however, quite succeeded in explaining — certainly not in a quantitive way.

The following is offered in the hope that it will supply the needed clew. The writer has been deeply interested in this question for a number of years, daily records of the dew-point having been kept for several years. He has spent a large proportion of his available time in endeavoring to bring the actual difference in coke consumption in summer and in winter into harmony with the quantity of moisture in the air in the two seasons, on the accepted basis of calculation as given in the lamented Sir Lowthian Bell's works, but the attempt was never a success. The actual difference was always several times larger than the calculated difference. This method of calculation, as is well known, consists in deducting the heat required for the dissociation of the water brought in, per unit of carbon, from the total heat developed under blast-furnace conditions by that unit of carbon. The clew to the fact that this could not possibly

be the real explanation was furnished by analysis of the top gases, which showed only traces of hydrogen at a time when there was a considerable quantity of moisture going into the furnace and there should have been 2 or 3 per cent of hydrogen in the top gas.

Its absence showed that it must have recombined with the oxygen from the ore at a higher region of the furnace (since water vapor could not possibly escape dissociation in the hearth), and in doing so must have restored to the contents of the furnace as much heat as it had previously abstracted from them, and therefore, on the basis of calculation mentioned above, its effect should have been *nil*, which, however, was very far from the case.

This being established, it was a short step to some work previously done to find out the reason for the utterly disproportionate economy produced in the blast furnace by the relatively small quantity of heat brought in by heating the blast, and it was eventually seen that these were merely two phases of the same problem, which could be satisfactorily solved only by having recourse to the conception of a critical temperature in the blast furnace at or above which only certain necessary operations of the furnace can take place.

The completion of these operations is essential to the success of the smelting operation and the heat available, for therein per unit of fuel is in many, if not most, cases the measure of the degree of economy that can be obtained under given conditions. I do not believe it possible in the present state of our knowledge to say exactly what these operations are, nor how much heat they individually require; but if the conditions of the combustion and the critical temperature are known, we can, with little difficulty, figure the quantity of heat available for their accomplishment, and for present practical purposes this is sufficient.

The critical temperature depends upon the conditions under which the furnace works; but ordinarily lies between 2700° and 3000° in coke practice. We will assume 2750° for the present case.

Before any work can be done by the combustion in the hearth and bosh at or above this temperature it is perfectly evident that the products of the combustion themselves must first be heated up to this temperature, and that the heat remaining from the combustion after this has been done is all that is

available for these necessary operations. To put it differently, if the entire heat developed by the combustion was first used to raise the temperature of its products, the amount of heat whose abstraction would reduce their temperature to this critical temperature (2750°) would be all that could be used for these high temperature operations. Given the temperature of the blast, quantity of moisture and percentage of carbon in the coke, we can readily calculate by ordinary rules what this amount is.

The assets of the combustion are: the combustion proper (carbon of coke to CO), the heat brought in by the coke (which is already at the critical temperature) and the heat brought in by the blast. Its liabilities are: first, the heat required for the dissociation of the moisture, and, second, that required to bring the products of the combustion to the critical temperature.

The balance is never a large quantity, seldom more than 1,500 B.T.U.'s per pound of fuel, and in the case of the conditions described by Mr.Gayley (ordinary moist blast) amounted to only about 1,100 B.T.U.'s. The removal of about one-half pound of moisture from every 1,000 cubic feet of air (3.5 grains per cubic foot, equal to about 0.03 pound per pound of carbon) increased this balance about 200 B.T.U.'s, and the addition of 150° to the temperature of the dry blast adds another 200 B.T.U.'s, making 400 B.T.U.'s, or just about 20 per cent in all; corresponding to the saving which resulted in practice. Similar methods of figuring account for many — in fact, nearly all — of the anomalies of blast-furnace fuel consumption.

Lack of space prevents the giving of details here, but those who desire can readily make similar calculations for themselves and will be surprised at the exactness with which they agree with practice.

The foregoing remarks have been sent to the secretary of the American Institute of Mining Engineers as a part of the discussion of Mr. Gayley's paper, and are contributed by permission to the " Iron Age " in advance of their publication by the Institute.

"The Iron Age," February 9, 1905. — At the December meeting of the Verein Deutscher Eisenhuettenleute, at the conclusion of Dr. von Linde's address on the new process, several of those

present expressed opinions. The first was Dr. Weiskopf of Hanover, who visited the Isabella furnaces in November with the members of the Iron and Steel Institute, and who began by testifying to the openness with which the furnace records were submitted to inspection on that occasion. He admitted that the constant watchfulness of an official of Mr. Gayley's standing would tend to better results without any addition to the plant, but denied that it could increase the production 24 per cent and simultaneously reduce the coke consumption 20 per cent, as the records show. He stated that the foreign visitors were astounded at the results obtained, and attempted to explain the true reasons for the same. The heat required to dissociate the small amount of moisture removed can certainly not account for the change, but avoidance of great variation in the moisture seems to be the key to the problem. It is most likely that the passage of steam over incandescent carbon and iron disturbs the equilibrium of the chemical reactions. These reactions, which take place between the mixture of gases $CO + CO_2$, and the solid bodies, iron, manganese, silicon, sulphur, etc., undergo a change on the introduction of steam, and there occur what may be termed reversible reactions, as shown below:

$$\text{I.}\quad C + H_2O \rightleftarrows CO + H_2$$
$$\text{II.}\quad 3Fe + 4H_2O \rightleftarrows Fe_3O_4 + 4H_2$$

The reactions indicated by the arrows pointing to the right, which must take place under the conditions, absorb heat, and, as recombustion of CO in the first and H in the second case is impossible, their heating value is lost, as it escapes in the gas, and additional heat is also required to again reduce the metallic oxides. Equation I would explain Mr. Gayley's assertion that there is more CO in the gas when using natural than when using dry air. Changes in the percentage of hydrogen in the gas have not yet been investigated, but to find out to what extent the reactions indicated really take place will be the object of experiments to be undertaken in the near future. It looks at present as though the results obtained must be ascribed to increased regularity in operation and the avoidance of factors that would disturb the chemical equilibrium or cause reactions which absorb heat. Regarding cost, Dr. Weiskopf stated that he was informed that the Isabella installation cost $125,000.00.

In order to bring out more clearly the different working of the furnace when the air is dry, the figures given in Table V of

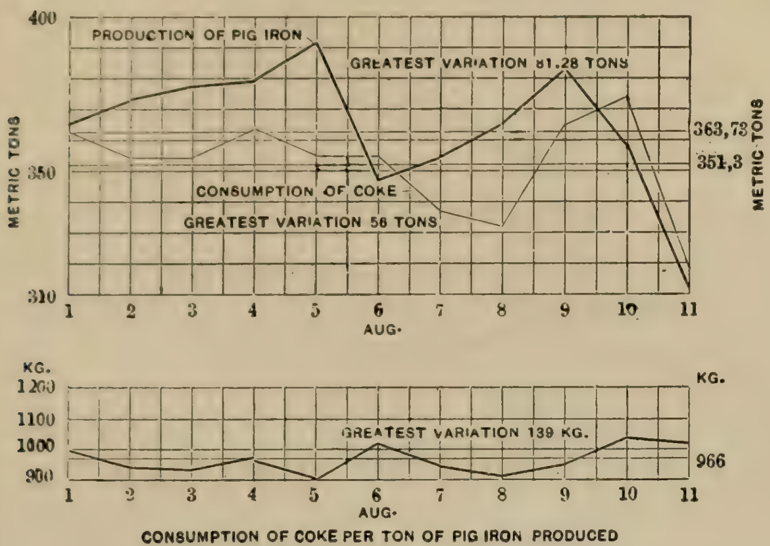

FIG. 1. With Air under Ordinary Conditions

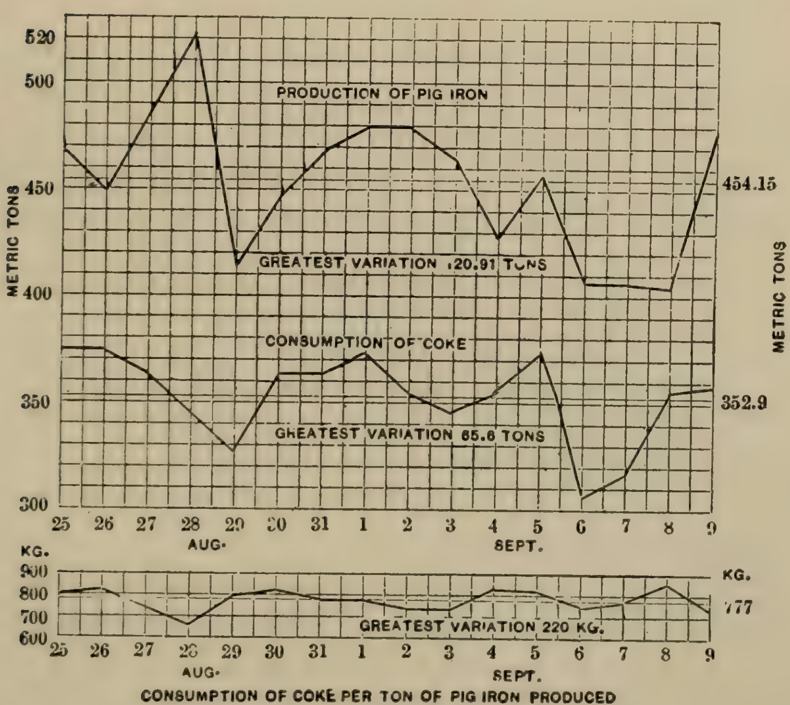

FIG. 2. With Dry Air

Mr. Gayley's paper have been plotted as shown in Figs 1 and 2. It will be seen in Fig. 1 that with moist air the lines representing production and coke consumption are relatively very irregular,

whereas with dry air, Fig 2, they rise and fall together, which indicates that the furnace is better able to accommodate itself to changes in production and fuel consumption by reason of its freedom from internal disturbance. It may also be seen from the table that the use of dried air does not preclude great variations in the daily output.

Mr. Gayley's Figures Criticized by Dr. Luermann

The next speaker was Dr. Luermann, the well-known consulting engineer of Berlin, who seemed very sceptical of some of the claims made for the new process. Regarding the decreased work of the blowing engines, he points out sundry apparent discrepancies in Mr. Gayley's paper. The diameter of the blowing tub is given as 84 inches and the stroke as 60 inches, so that, neglecting the piston rod, the displacement would be almost 385 cubic feet per revolution. In another place it is stated that at 114 revolutions per minute the engines were supplying 40,000 cubic feet of air, which would be equivalent to 351 cubic feet per revolution, or 34 cubic feet less than the amount found by the above calculation. Immediately below it is stated that with dry air the engines ran at 96 revolutions per minute, or 18 revolutions slower than before, and that thereby the column of blast was reduced over 6,000 cubic feet. This would show $\frac{6,000}{18} = 333$ cubic feet per revolution. Thus there are three different values given for the volume of air per revolution. If the engines ran the whole day, or 1,440 minutes, without stopping, there would be $6,000 \times 1,440 = 8,640,000$ cubic feet less air required. This figure cannot be right if the figures for production and coke consumption in the two periods when moist and dry blast were used, as given in Table V, are correct, as is shown by the following calculation: In the period without dry blast the average production was 358 tons with a coke consumption of 2,147 pounds per ton. The coke consumption for one day would therefore be 768,626 pounds; of this amount there would be required for the dissociation of water in the furnace $358 \times 77.16 = 27,623$ pounds. The remainder, $768,626 - 27,623 = 741,003$ pounds, would be gasified by the residue of moisture and the oxygen of the air. In the second period during which dried air was used there were gasified $447 \times 1,726 = 771,$-

522 pounds of coke by means of the oxygen in the air and the residue of moisture, which was the same in both periods. The blowing engines must, in the latter case, deliver more, not less, in the proportion 741,003 : 771,522. As the supply of air in 24 hours previously amounted to $1,440 \times 40,000 = 5,760,000$ cubic feet, the increase would amount to 2,372,317 cubic feet. The difference between the saving in blast claimed by Mr. Gayley, $6,000 \times 1,440 = 8,640,000$, and the increase really required, as calculated above, amounts to 11,012,317 cubic feet, which corresponds to $\frac{11,012,317}{40,000} = 275$ minutes, or $4\frac{1}{2}$ hours' work of the engines.*

Another method of calculation leads to similar impossibilities. Mr. Gayley claims to have removed 69 pounds of water per ton of iron using air which originally contained 5.66 grains moisture per cubic foot, of which 3.91 grains had been taken out According to this, the engines only had to supply $\frac{69 \times 7,000}{3.91} =$ 123,529 cubic feet of air per ton of iron, or $\frac{123,529}{2,147} = 57.5$ cubic feet per pound of coke. In Germany, with good blowing engines, it is usually reckoned that 80 cubic feet of air per pound of coke are necessary. If the amount of air be calculated from Mr. Gayley's data, that at 114 revolutions per minute the engines supplied 40,000 cubic feet per minute, equal to 57,600,000 cubic feet in 24 hours, we obtain as the amount of air per pound of coke $\frac{57,600,000}{768,626} = 75$ cubic feet. This is 17.5 cubic feet per pound of coke, or 37,364 cubic feet per ton of iron, more than found by the previous calculation. Again, the statements that 69 pounds of water were removed per ton of iron and that this amount would be equivalent to 23,192 pounds of water per day do not agree, as this would make the average production $\frac{23,192}{69} = 336$ tons, while that given in the table is 358 tons.

Dr. Luermann shows by calculation that the removal of

* Note by the Translator. — Dr. Luermann seemingly ignores the increased density of the air, owing to its lower temperature, but this, although considerably lessening the discrepancy between his figures and those of Mr. Gayley, does not entirely remove it.

69 pounds of water per ton of iron would result in a saving of only 77 pounds of coke, equivalent to 3.58 per cent, whereas Mr Gayley claims a saving of 421 pounds, or 19.6 per cent. He expresses his disbelief that 2,147 pounds of coke are ever used in this country to produce a ton of iron, and in support of his position quotes figures which have been published from time to time of extraordinarily favorable coke practice at Duquesne and South Chicago.

Professor Osann Defends Mr. Gayley

Dr. Luermann was followed by Professor Osann, who remarked that in view of the statements of some of those present, he quite believed in the accuracy of Mr Gayley's figures for production and coke consumption in spite of the discrepancies pointed out by the previous speaker. Regarding the theory of Mr. Schmidhammer, alluded to above, he contended that an error in calculation had been made and that the increased pyrometric effect would be only 114° C. instead of 171° C. Further, that the same result would be obtained by raising the temperature of the blast 140° C., but that it was well known that this would not effect a saving of 20 per cent of coke, but of 5 or 6 per cent at most. He suggests that the furnace may have been getting too much coke before, and that the mere fact of reducing the coke caused the furnace to work better. He also suggests that the faster working made possible by the decreased load on the engines is responsible for the lower coke consumption. Finally, he thinks it possible that the valves between the furnace experimented on and its neighbor were not tight and so gave rise to errors.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

MODES of Testing Castings. W. T. MacCall. "The Mechanical World," February 10, 1905. 2,800 w. Abstract of a paper read before the British Foundrymen's Association. — The author describes briefly the ordinary tests applied to castings, including the transverse, tensile and crushing tests. **No. 328. A.**

The Pintsch Suction Gas Producer. S. F. Saeger. "Engineering News," February 16, 1905. 1,800 w., illustrated. Abstract of a paper read before the Michigan Engineering Society. **No. 329. A.**

By-Product Coke as Made by the Coke Oven Plant of the Otto-Hoffman and United-Otto Types, Camden, N. J. E. A. Moore. "The Iron Trade Review," February 9, 1905. 13,000 w., illustrated. — Paper read before the Philadelphia Foundrymen's Association, Philadelphia, February 1, 1905. **No. 330. A.**

Continuous Process for Car-Wheel Manufacture. "The Iron Trade Review," February 2, 1905. 2,000 w., illustrated. — Describes the manufacture of car wheels by the Sherman process, at a plant near Pittsburg. The device consists of an endless track and mold conveyor. **No. 331. A.**

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Thermometers and Pyrometers with Some of Their Industrial Applications. Robert S. Whipple. "Engineering," February 17, 1905. 6,000 w., illustrated. — A paper read before the Cleveland Institution of Engineers, December 5, 1904. **No. 332. B.**

Solid Rolled Steel Chains. Peter Everymann. "The Iron Age," February 16, 1905. 1,500 w., illustrated. — The author describes the Klatte method of producing solid steel chains by a single rolling process. **No. 333. B.**

Notes on Cranes. The Wellman Furnace Charging Machine. A. D. Williams. "American Machinist," February 2, 1905. 600 w., illustrated. — An illustrated description of several types of charging machines manufactured by the Wellman-Seaver-Morgan Company, of Cleveland, O. **No. 334. A.**

Procédé Electro-Métallurgique Froges-Héroult. (The Froges-Héroult Electro-Metallurgical Process). Ch. Combes. "Electrochémie," December, 1904. 3,000 w. — A description of the manufacture of steel by the Héroult process at La Praz. **No. 335.**

Gussfehler an Stahlugussstucken (Defects in Steel Castings). Paul Friem. "Stahl und Eisen," January 1, 1905. — The author describes the occurrence of cracks, blowholes and other defects in steel castings and the methods used for their prevention. **No. 336. D.**

Mitteilungen über die Flusseisendarstellung im Siemens-Martinofen (The Manufacture of Low-Carbon Steel by the Open-Hearth Process). H. Gensmer. "Stahl und Eisen," December 15, 1904. 6,000 w. — The author describes some recent progress in the production of low-carbon steel in the open-hearth furnace. **No. 337. D.**

Trocknung des Hochofenwindesmittels Kältemaschinen (The Drying of Furnace Blast by Refrigeration). C. von Linde. "Stahl und Eisen," January 1, 1905. 4,000 w. — The author describes the Gayley process of drying the blast and gives estimate of the cost of the operation. **No. 338. D.**

Sur la Fragilité de Certains Aciers (The Brittleness of Certain Steels). A. Perot and H. M. Lévy. "Comptes Rendus." 700 w. — The authors describe the influence of the speed of the drop upon the results of impact tests. **No. 339.**

Le Poinçonnage Envisagé comme Méthode d'Essai (Punching Considered as a Testing Method). L. Baclé. "Bulletin Sociétié d'Encouragement," November 30, 1905. 3,000 w. **No. 340. D.**

Recherches sur les Aciers au Vanadium (Researches upon Vanadium Steels). Léon Guillet. "Génie Civil," January 7, 1905. Part I, 2,000 w. — The author describes the influence of vanadium added to nickel steel. **No. 341.**

METALLURGICAL NOTES AND COMMENTS

Samuel Thomas Wellman

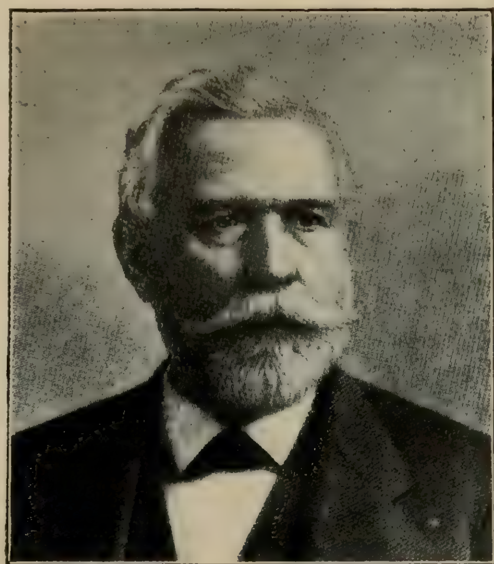
As a frontispiece in the present issue of the *Iron and Steel Magazine*, we reproduce a recent photograph of Samuel Thomas Wellman, the well-known engineer and metallurgist to whom the iron and steel industry is indebted for so many invaluable labor-saving devices and improvements in metallurgical appliances.

Mr. Wellman was born on February 5, 1847, in Wareham, Mass., where he received his early education, afterwards attending the Norwich University, at Norwich, Vt. In 1866, he secured employment at the works of the Nashua Iron Company, Nashua, N. H., where his services were so satisfactory that in a very few years he became superintendent of the works. Mr. Wellman left the Nashua Iron Company to accept the position of engineer and general superintendent of the Otis Iron and Steel Company of Cleveland, Ohio. In 1890, he founded the Wellman Iron and Steel Company of Thurlow, Pa., assuming the presidency of the company. Four years later Mr. Wellman organized the well-known firm of "The Wellman-Seaver Engineering Company" (now the Wellman-Seaver-Morgan Company), an undertaking which was highly successful from the start and soon acquired a world-wide reputation. The wide range of work carried on by this representative American firm is well known to our readers. It includes consulting engineering, the designing and building of complete iron and steel works and blast-furnace plants, the erection of buildings and structural works, etc. The firm has given close attention and has been especially successful in the construction and installation of the well-known Wellman rolling open-hearth furnace, introduced in 1889, and of which probably over one hundred are now in use, in the designing and installation of rolling mills and rolling mill machinery, of charging machines for the open-hearth furnace, of cranes, ingots, conveyors and other hoisting and transferring machinery, of gas producers and coke-oven machinery.

Mr. Wellman is a past president of the American Society of Mechanical Engineers and of the Cleveland Engineers' Club, and a member of many engineers' societies and other influential clubs.

William Sellers

By the recent death of William Sellers, which occurred in Philadelphia, January 24, the engineering profession and the business world loses one of its most honored and successful members. The following short biographical sketch of his life is abstracted from a recent issue of "The Iron Age."



"William Sellers was born in Upper Darby Township, Delaware County, Pa., September 19, 1824, on an estate still held by the family under the original patent granted to Samuel Sellers in 1682. He received his education at a private school built and conducted by his relatives. Having a taste for mechanics, at the age of fourteen years he entered the machine shop of his uncle, J. Morton Poole, on Brandywine Creek. He completed his apprenticeship at the age of twenty-one, and then moved to Providence, R. I., where he became foreman for Fairbanks, Bancroft & Co., manufacturers of engines and mill gearing. In 1847, he returned to Philadelphia and started in business on his own account. Shortly afterward he formed a partnership with Mr. Bancroft, one of his former employers, under the name of Bancroft & Sellers. Upon the death of Mr. Bancroft, which was in 1855, the firm name was changed to William Sellers & Co. Upon the incorporation of the firm in 1886 he was made president and engineer. In 1868, Mr. Sellers organized and became president of the Edgemoor Iron Company, Edgemoor, Pa., manufacturers of bridges, now a constituent part of the American Bridge Company. In 1873, he became president of the William Butcher Steel Works, Nicetown, Pa., and reorganized it as the Midvale Steel

Company, serving as president until 1887. He accepted the position of president of the Franklin Institute in 1864, when it was in a critical financial condition. By his energy and wisdom it was reconstructed and placed on a sound basis. During his presidency of the Institute he read a paper before the members on "Screw Threads and Nuts," in which he proposed the first formula ever offered for a system of making screw threads, which has since become the standard for the United States and the continent of Europe. Mr. Sellers took a deep interest in public affairs. He was a park commissioner of Philadelphia from 1868 to 1872, member of the National Academy of Sciences since 1873, vice-president of the Centennial Board of Finance for the International Exposition of 1876, corresponding member of the Société d'Encouragement pour l'Industrie Nationale, France, since 1875, and was made a Chevalier of the Legion d'Honneur in 1889 for his services in connection with the Paris Exposition. Much of the success of the Centennial Exposition at Philadelphia was due to his business ability and assiduous application to its interests. He was for several years a director of the Philadelphia & Reading Railroad and of the Philadelphia, Wilmington & Baltimore Railroad. In 1868, he was elected a trustee of the University of Pennsylvania. He is survived by a daughter and three sons."

Successful Blast-Furnace Use of By-Product Coke

The older members of the iron trade will recall the mass of by-product coke propaganda with which some American technical publications were filled a dozen years or more ago, and how little effect on industrial operations the campaign exerted. Of late years, and without such public exploitation, the manufacture of by-product coke in the United States has made great headway. Several important steel producers have adopted the by-product oven, building their coking plants contiguous to their blast furnaces instead of contiguous to the coal mine. In some cases there have been difficulties, but they may have been due entirely to the coal employed.

The Dunbar Furnace Company, Dunbar, Pa., started with a battery of some 50 or 60 ovens, and has since increased the number to 110. Its ovens are of the Semet-Solvay type. A part of the product is sold for foundry use, in which employment it has received cordial approval, one large interest using this

coke exclusively. The company uses this coke in its Dunbar furnace, and this furnace in the week ending Saturday, March 11, broke its record for a week's production by making 2,011 tons of pig iron. The greatest day's record was 322 tons. As this furnace was built to make 250 tons, the record is entirely satisfactory. The coke consumption has run regularly at less than a short ton of coke to a long ton of pig iron, and during the record week the consumption was, of course, decreased from this average. Coal from the standard Connellsville vein is used, Dunbar itself being only four miles from Connellsville.

The Increasing Tonnages of Steel Required by Railroads. — Railroads are at present the largest users of iron and steel, and their recent policy of restricting their purchases only to their actual necessities is responsible, more than anything else, for the slackness in mill orders during the last eighteen months. But all this time the railroads have been piling up their needs, and when these wants shall be met they will be greater than when they first developed. To be more explicit, rails and bridges that should have been bought in 1903 and 1904, when they are bought in 1905 will rule 10 to 20 per cent heavier than they would have been if they had been ordered when first needed. This increase in weights of rails and bridges is necessitated by the constantly increasing tonnages of locomotives and cars made obligatory by the necessity of decreasing the ton-mile cost of handling freight.

As mileage can be reduced only fractionally, and then at immense cost through eliminating curves and grades, the only means by which railroads can reduce their ton-mile cost is by the use of heavier and more powerful locomotives and heavier and more capacious cars. It was not many years ago that the minimum freight carload was 12 gross tons, or 22,400 pounds. A little later this was increased to 15 net tons, or 30,000 pounds, and this minimum has increased until many roads schedule 40,000 pounds as their minimum carload. Maximum carloads have increased in the same proportion and now range from 60 to 100 net tons on coal and ore carrying roads and 40 to 60 tons for ordinary commercial freight.

To draw trains of the heavier cars, locomotives have increased from 150,000 to 175,000 pounds weight in the eighty's

to 350,000 to 400,000 pounds weight to-day, and the limit has not yet been reached.

Roadbeds and bridges have had to be strengthened to accommodate these increasing loads. Rails bought to-day for trunk lines range from 80 to 90 pounds to the yard, and in some instances 100 pounds and heavier, whereas the rails that are being taken up and sold for scrap after 8 or 10 years' service range from 50 to 70 pounds. For the same reason railroad bridges that would otherwise have many years of service before them are being scrapped and replaced by heavier structures. Until recently railway bridges were built for a maximum live load of 3,500 pounds per lineal foot, and that was thought to be sufficient for all possible increase in tonnage during the natural life of the structure; but to-day trunk-line bridges are designed for live loads of from 6,000 to 7,500 pounds per lineal foot. The increasing weight of iron and steel for railroad purposes does not stop here. As train loads increase it becomes necessary to increase the strength and consequently the weight of the draw bars and couplings of all cars that are intended for general traffic, as well as the framework of the cars themselves. A 12-ton capacity car of 20 years ago would pull apart like a lunch box if put at the forward end of a modern heavy trunk-line freight train.

It will thus be seen that the railroads are consuming constantly increasing tonnages of iron and steel in proportion to their mileage, and that this tendency will continue until the highest factor of efficiency and consequently the lowest possible ton-mile cost of haulage is reached. It is not merely a matter of replacing rails and bridges, locomotives and cars, with heavier ones when the old ones are worn out, but it is more frequently a case of discarding the old for the new before the old equipment has seen half the years of its intended service. Freight cars cannot be made much longer or wider than the present maximum as long as existing curves have to be negotiated, but they may be made higher, because the almost universal use of the air brake no longer makes it necessary to allow for the brakeman between the car roof and the overhead bridge or viaduct. Their carrying capacity is also being augmented by the substitution of steel for wood. The steel car industry has already become one of the largest consumers of steel in the country, and the advantages of

the steel car outweigh its disadvantages to such an extent that each year steel is being used more and timber less in the construction of freight cars. When one considers that the normal life of steel rails, and probably on an average of all other steel and iron materials that enter into American railroads, is ten years, and that, therefore, of the millions of tons now in use 10 per cent must be replaced annually, to say nothing of the increasing mileage and the necessity of replacing so large a proportion of the equipment long before the ten-year life has been lived, there is much encouragement to the steel maker. "The Iron Age," December 15, 1904.

New Process for the Treatment of Blast-Furnace Slag. — A new process, which may prove to be of considerable importance in the near future to ironmasters, involves an entirely new departure in the treatment of ordinary blast-furnace slag. Many attempts have been made in the past to treat this material in order to render it valuable for road-making and other purposes, but the inherent defects of any such treatment have caused disappointment and failure — even in the best and most recent of them — when the finished material has been submitted to the test of heavy traffic and varying climatic conditions.

A perfect, cheap and easily managed agent was therefore necessary before the enormous deposits of old slag could be utilized successfully for this purpose. Certain recent attempts have been made, by dealing with the hot slag, to render it proof against the evil effects of moisture and frost, but without much success. The reheating of the slag has also been tried, but this again is a costly process, necessitating somewhat expensive machinery, and in the act of reheating, certain of its properties are changed or eliminated. Nothing had been discovered which would penetrate the cold, damp or wet slag, and either expel the moisture or render it powerless, while making the material waterproof and leaving it as hard as, or harder than, before. The discovery of such an agent would necessarily mean a transformation in the value of millions of tons of old refuse now on the dumps, in the cost of removing it from the furnaces, and in the release of valuable land. A strong claim is now made that the problem has been at last successfully solved after long and patient research and experiments by scientists of undoubted repute.

A well-known engineer who was present at a demonstration of the process has made a written statement that the results are satisfactory. He has tested the slag after the treatment, and finds that it is rendered in one simple inexpensive operation absolutely waterproof and coated with a preparation of tar and pitch, which in the opinion of road surveyors and contractors will make a road dustless and immune against water, frost, snow, heat or any other weather change.

The value of such a road is apparent. Once laid (and we understand the cost will not be more than the ordinary tar macadam road, if so much), a good surface is formed, the cost of cleansing and repairing reduced to a minimum, its life increased and the dust, which is at present seriously detrimental to the value of adjacent property, and one of the most objectionable features in motoring, will be practically abolished.

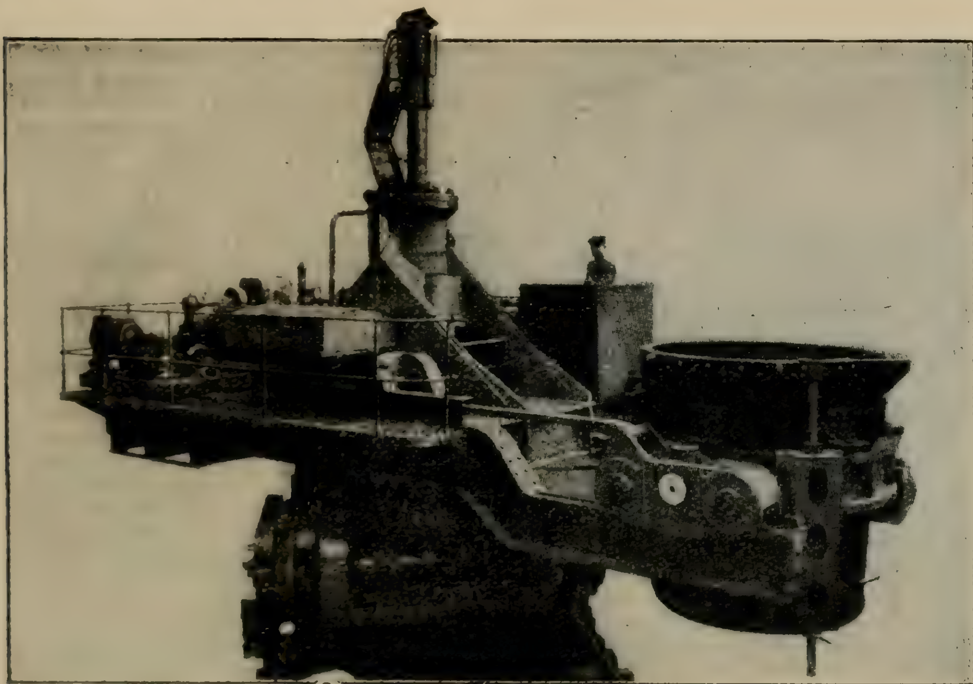
The fault of other agents hitherto used is that they become more or less quickly volatile and ultimately disappear, but the newly discovered "Zorene," which is the name given to the mixture used in the new process, remains effective so long as a particle of the treated substance exists. The defects in the continental methods of dealing with slag for the manufacture of paving slabs, cobbles, etc., are claimed to be overcome by the "Zorene" treatment, and, this being so, the British slag owner should now be in a position to deal profitably with his accumulated deposits.

An additional importance is claimed for the "Zorene" treatment by the fact that it can be as easily applied to the hot as to the cold slag, the cost in either case being considerably below anything hitherto attempted in this direction. Another of the valuable properties claimed for "Zorene" is that it is a perfect germicide. The unhealthy and unsavory condition of the roads in many cities and suburbs is rapidly becoming a question of vital importance, and the discovery is therefore of value from a hygienic point of view.

The sole rights in the process are vested in "Zorene," Limited, 47 Victoria Street, Westminster; but we understand that a new company is in course of formation for the development of the process in the United Kingdom. "The Iron and Coal Trade Review," February 10, 1905.

Locomotive Casting Ladles. — We give an illustration and description of an electrically operated casting ladle, a type now largely used in Continental steel works. These ladles require no special locomotive for haulage nor crane for lifting and tilting. In fact, the makers claim that the use of one of these quick-working casting ladles means an increased output and the highest obtainable economy.

There are two main parts, the platform carrying the ladle and operating mechanism, and the truck which is mounted on six wheels. A forged steel center pivot is rigidly connected to



Locomotive Casting Ladle

this truck and carries a plunger to which a strong spur-wheel is keyed at the lower end. This wheel gears into a 12 horse-power slewing motor placed in the truck.

The raising and lowering of the platform is performed by hydraulic power, a cylinder being arranged on top of the center pivot. To this cylinder the platform is connected by strong triangular suspension plates. The hydraulic pressure is produced by a slow-running three-cylinder pump, which is driven by a 50 horse-power electric motor. The pump draws from a small feed tank at the rear side of the platform, and the water is

automatically returned to the tank after each lifting operation. This combination of electric and hydraulic power we understand has proved very satisfactory.

The ladle itself is placed on sliding carriages to allow for a short travel on the platform. The tilting of the ladle is effected by worm and wheel and countershaft geared to a separate 12 horse-power motor. The locomotion of the complete machine is performed by two 50 horse-power motors coupled to the rear axle of the truck, giving it a speed of 300 feet per minute. The operator's stand is conveniently arranged so that the truck and the casting pit can be clearly observed. There are only four levers to attend to. The first sets the motor and pump in motion for lifting the platform and automatically controls the water valve. The second lever works a universal controller by which the slewing of the platform and the locomotion of the whole appliance is controlled. A third lever actuates the motor for tilting the ladle, and the fourth starts the motor for sliding the ladle on the platform.

These electric locomotive casting ladles are built for capacities up to 40 tons, by the Benrath Engineering Company, whose London office is at 36 Victoria Street, S.W.

Mold Drying Method for Steel Castings. — Forgings are gradually being replaced by cast steel in the construction of locomotive frames, not only on account of the lower cost of the steel, but because the steel suitable for frames shows a tensile strength of about 75,000 pounds per square inch as compared with 53,000 to 54,000 pounds per square inch for the best hammered iron. In addition, the cast-steel frame is practically homogeneous, having no welds, and is of uniform texture throughout its entire length. Furthermore, the number of projections required for the reception of brake work, tumbling shafts, rocker pins, etc., seriously complicates the production of the frames of hammered iron, whereas the reverse is true in the manufacture of cast-steel frames.

Owing to the length of the frames, varying up to nearly 40 feet, considerable difficulty has been experienced among steel-casting manufacturers in producing them without shrinkage cracks and the consequent loss of an unduly high percentage of castings. C. C. Smith, of the Union Steel Casting Company,

Pittsburg, has a patented method of drying molds in his plant by which this difficulty has been entirely overcome. The common practice of drying the molds throughout is objectionable in the manufacture of large steel castings, not only on account of the danger of injuring the mold in its removal to the drying oven, but also because the baked mold does not break or disintegrate under the shrinkage of the casting, and as a result the latter becomes strained and frequently full of shrinkage cracks. By the new method only the face of the mold is baked, leaving the main body easily friable, so that the mold will readily break down under the strains due to the shrinkage of the casting.

In drying the mold the cope is superimposed on the drag and a perforated gas pipe is introduced between them, the gas being burned in the mold cavity between the cope and the drag.

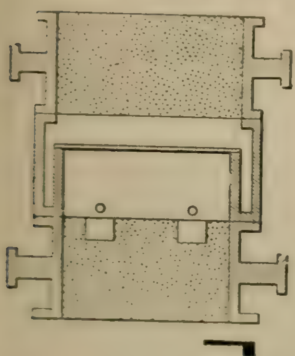


FIG. 1 Method of Placing Cope over Drag

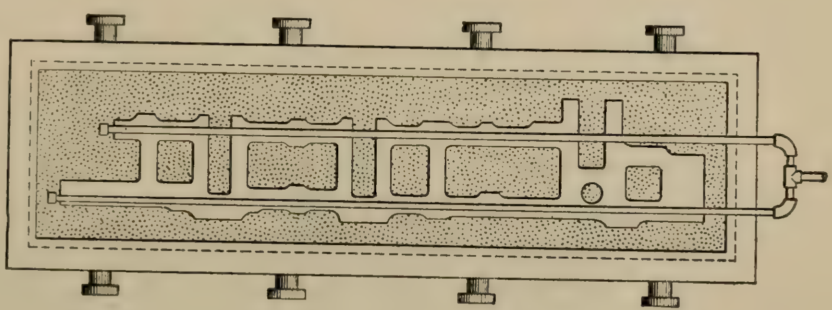


FIG. 2. Piping Arranged for Drying Locomotive Frame Mold

A flask section is placed between the cope and the drag to hold them some distance apart, and to prevent the drying of the cope to a greater extent than the drag a baffle wall of thin metal prevents the flame from coming in contact with the cope face. The heat can be continued for any length of time so as to get thoroughly dry mold faces. While the face of the mold will become dry and hard the greater portion of the mold body will still be moist and will easily disintegrate or break down. In the drying of molds for locomotive frames two perforated gas pipes are used, as in Fig. 2. This method of drying can be carried out on the molding floor, not necessitating the removal of the drag or cope to a drying oven, the cope receiving a minimum amount of handling, while the drag is not moved at all. The Union Steel Casting Company has been successfully making

locomotive frames by this method for the past year and a half and is at present producing six daily. "The Iron Trade Review," February 2, 1905.

The Manufacture of Iron at Tidewater. — With the increasing interest taken in foreign trade the movement toward locations on tidewater may be expected to show interesting developments in the near future. It is true that some quite important plants now thus situated have not shown the growth in this respect which had been anticipated, but in nearly every case they have been hampered by lack of capital. The time appears to have passed when from a moderate investment a manufacturing enterprise can steadily make accretions by means of its profits and eventually become a huge establishment, able to hold its own in any field it enters. In these days capital is required on a vast scale to make an impression in trade. The ground occupied must be fortified at every point, and this requires money. With ample capital a location on the seaboard promises great opportunities to the steel manufacturer of the future. The requirements of the world are steadily increasing, and this country, as has been shown in recent years, can get its share of that trade if proper efforts are made to get it.

In Europe, tidewater, or, as they are often termed, "littoral," iron and steel works have been increasing in number. In England certain districts, like the Cleveland, have always enjoyed the advantage of tidewater location, coupled in that case with special advantages in regard to proximity to local raw materials. In Wales the plants have moved from the interior location at the coal to the ports. In France such an enterprise as Creusot, located at the coal in the interior, has placed a new blast furnace at Cette, on tidewater. In Austria there are new furnaces at Trieste; in Italy pig-iron making is established in Elba; in Germany large works have been built at Dantzic, while Hamburg has been proposed as an iron-making center.

In many cases these plants rely upon sea-borne ores and fuel from the back country; in others they assemble all raw materials by water.

A number of factors enter into this movement to the sea. Primarily, of course, a tidewater location looks to cheap distribution of products in coastal domestic and in foreign markets.

The location is then dependent upon the flow of heavy tonnage of all kinds. Another point is that the quantity of ore is fixed, which creates a general tendency, other things being equal, to cause position closer to the ore to become more advantageous. But one variable factor has a more and more pronounced effect, and that is the steady reduction which is taking place in the quantity of fuel needed for iron manufacture. This makes the works increasingly independent as to location from the coal fields, and the Gayley dry-air process promises to further emphasize this tendency.

Finally, the by-product oven is playing a greater rôle. When located in a large industrial center the by-product oven, with certain coals, becomes an apparatus whose main function is to produce gas for industrial purposes, recent improvements in its enrichment giving it a higher lighting power at a slight additional cost.

As applied to our own Altantic coast, and to New York harbor in particular, these considerations have greatly changed underlying conditions, to which must be added the probability that before many years elapse the duty on foreign ores is likely to be repealed.

All these matters are now being given careful thought by important groups of capitalists, and the day is probably not far off when New York, and possibly some New England points, will become important centers of iron and steel manufacture. "The Iron Age," February 2, 1905.

World's Consumption of Iron. — In the first centuries of the iron age, says N. S. Shaler in the "International Review," the requisition was much less than a pound each year for each person. Four centuries ago it probably did not exceed, even in the most civilized countries, ten pounds per capita each year. It appears to have been at something like that rate when the English colonies were founded in North America. At the present time in the United States it is at the average rate of about 400 pounds per annum for every man, woman and child in the land, and the demand is increasing with startling rapidity. It seems eminently probable that before the end of the present century, unless checked by a great advancement of cost, it will require a ton each year to meet the progressive desires of this insatiable man.

When the American English colonies were founded, coal had hardly begun to come into use in any country. It is doubtful if the output of the world amounted at that time to 100,000 tons — possibly to not more per capita of the folk in Europe than a pound, or about the same as iron at that late period in the so-called "iron age." At the present time the total production of Europe and North America amounts to an average of at least two tons per each unit of the population, and the increase goes on at a high ratio. "The Iron and Machinery World," February 18, 1905.

Alloys Research Committee. — Since the presentation in January, 1904, of the late Sir William Roberts-Austen's last report, the Alloys Research Committee, under the chairmanship of Sir William H. White, has continued its work at the National Physical Laboratory. Dr. Glazebrook, director of the laboratory, has arranged a series of investigations on specimens of nickel steel presented by Mr. R. A. Hadfield, a member of the committee. It is anticipated that a further report will be presented this year by the committee, communicating the results of these researches. The names of Prof. J. O. Arnold, Dr. A. Barr, Mr. F. W. Harbord and Mr. J. E. Stead have been added to the committee. Further investigations having great practical importance are now being considered. "Page's Weekly," February 17, 1905.

A Grant from the Carnegie Institution. — Announcement has been made by the Carnegie Institution through its president, Dr. R. S. Woodward, of the award of a special grant of $2,500 to Prof. Charles F. Burgess, of the department of electro-chemistry and electro-metallurgy of the College of Engineering of the University of Wisconsin, at Madison, with which to pursue his investigations on the property of pure iron and its alloys.

United States Steel Corporation. — The net earnings of the United States Steel Corporation for the quarter ended December 31, 1904, compare as follows with the net earnings in the same quarter for the three preceding years: 1904, $21,458,734; 1903, $15,037,181; 1902, $31,985,759; 1901, $29,759,913.

The unfilled orders on the books on December 31 last,

aggregating 4,696,203 tons, compare with 3,215,123 tons on December 31, 1903; 5,347,253 tons on December 31, 1902, and 3,027,436 tons on December 31, 1901.

The unfilled orders increased 1,668,767 tons in ninety days, the total orders on the books on October 1 last being 3,027,436 tons. There are now on the books orders exceeding 5,000,000 tons. "The Bulletin," American Iron and Steel Association, February 15, 1905.

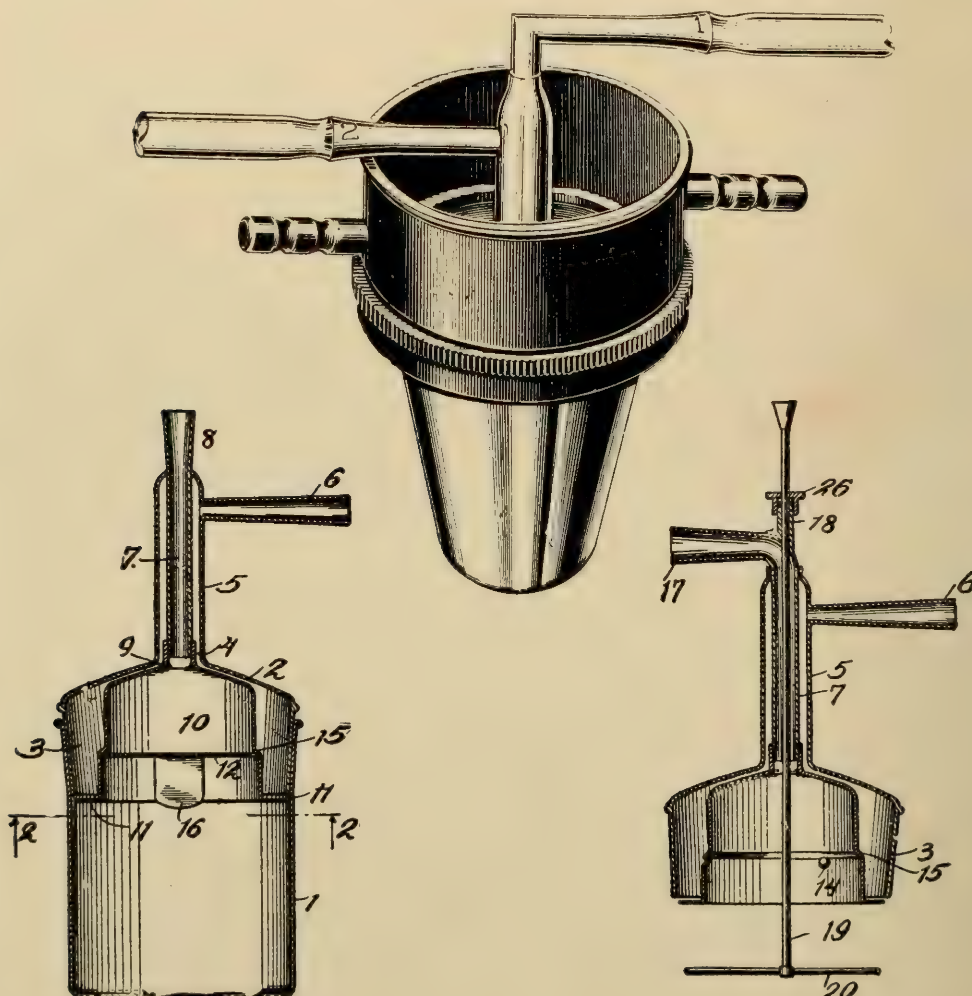
Iron and Steel Institute Meetings. — The annual general meeting of the Iron and Steel Institute will be held at the Institution of Civil Engineers on May 11 and 12. The annual dinner will be held — under the presidency of Mr. R. A. Hadfield — in the grand hall of the Hotel Cecil, May 12. Awards for Carnegie research scholarships will be announced at the meeting. The autumn meeting will be held in Sheffield, September 25–29. The reception committee in Sheffield includes the Lord Mayor as chairman, and the Master Cutler as vice-chairman. The chairman of the Executive Committee is Col. H. Hughes, C.M.G.

Members are invited to participate in an International Congress of Mining, Metallurgy, Mechanics and Applied Geology, to be held at Liége, Belgium, on June 26 to July 1, in connection with the International Exhibition. The subscription to the Congress is 25 francs, and members should enter their names in that section of which they wish to receive the publications. The general secretary of the Organizing Committee is Mr. Henri Dechamps, 16 Quai de l'Université, Liége. The subjects to be dealt with in the metallurgical section comprise coke manufacture; blast-furnace practice; influence of titanium, arsenic and other substances on iron and steel; removal of dust from blast-furnace gas; slag cement; use of poor gas as motive power in rolling mills; new methods of open-hearth steel manufacture; alloys of steel with chromium, nickel, manganese, vanadium and tungsten; the forging press and steam hammer; electrometallurgy and the practical applications of metallography. Further particulars may be obtained from the secretary of the Iron and Steel Institute, London, Mr. B. H. Brough.

Crucible for the Determination of Carbon by Combustion. — The accompanying illustration shows a new patented form of

crucible for the determination of carbon by combustion, manufactured by Eimer & Amend, New York.

This apparatus is made of platinum and so arranged that the entering air or oxygen is superheated and does not blow directly on the substance to be treated. The gases CO and CO_2 escape slowly through a chamber in the top of the apparatus which is provided with granulated copper oxide to effect perfect



oxidation, thus doing away with the cumbersome water-cooling and special copper-oxide tube. According to the makers, combustions can be made in about half the time without any loss of material and without danger from organic matter as in the older rubber-joint forms. It may be provided with stirring arrangement, and can be had of straight or conical form to admit a Gooch crucible, saving transferring.

The Determination of Chromium in High-Speed Steels and Alloys.— The simplest and most rapid method of estimating chromium consists in its conversion to a salt of chromic acid, followed by titration with a ferrous iron solution and potassium permanganate or bichromate. Oxidation in a solution can be accomplished in many ways, but no oxidizing agent acts so quickly and effectively as the potassium or ammonium salt of persulphuric acid.

The present retail price of these compounds — about eight shillings a pound in the case of the ammonium salt, and, on account of its smaller solubility in water, only about five in the case of the potassium salt — is by no means prohibitive, and they are now being used extensively for oxidizing and other purposes. Amongst others, the conversion of the manganese in a steel into permanganate is worthy of mention.

As practiced by the author, the oxidation and subsequent determination of chromium in a steel can be conducted in the flask into which the drillings are first weighed, without resorting to a single filtration, and duplicate assays can easily be made in less than an hour.

Process for Steels. — Half a gram of the drillings are placed in a small flask and covered with 10 cubic centimeters of dilute sulphuric acid (1 acid to 4 water). Heat is applied to assist the breaking up of the steel, and when decomposition is complete, or nearly so, a few drops of strong nitric acid are added to oxidize the iron, and the nitrous fumes thus generated are then expelled by boiling. About 100 cubic centimeters of water are next added, together with 20 cubic centimeters of nitric acid (specific gravity 1.20), and 20 cubic centimeters of a solution of silver nitrate, made by dissolving 2 grams of the crystals in a liter of distilled water. Two or three grams of solid ammonium persulphate are then added, and, after washing down any particles of the salt adhering to the neck or sides of the flask, the whole mixture is heated.

Oxidation of the chromium (and the manganese) soon sets in, and the green color of the solution is replaced by the characteristic yellow of chromates. This may be modified or masked completely by the purple tint of the permanganate formed from steels containing manganese. High-speed steels, however, con-

tain only a trace of this element, and many none at all, so that there is no appreciable interference from this source.

As the temperature rises, a brisk evolution of oxygen gas sets in, due to the decomposition of the excess of ammonium persulphate. This decomposition is brought about catalytically by the silver nitrate added. The expulsion of oxygen should be assisted by frequent shaking, so that it has practically ceased when boiling point is reached. The solution may then be boiled not longer than half a minute, after which it is cooled off rapidly under the water tap.

Without filtering off the tungstic oxide, which has separated in considerable quantity, the solution is largely diluted, and an excess of a ferrous sulphate solution, of approximately one-twentieth normal strength, added to reduce the chromic acid. The excess of ferrous iron is then titrated with potassium permanganate of the same strength.

$$1 \text{ cc. } \frac{N}{20} \text{ potassium permanganate} = 0.000868 \text{ grams chromium.}$$

The end point of the reaction is not materially obscured by the precipitated tungstic oxide.

Process for Alloys. — The procedure just described for steels is applicable in its entirety to rich chromiferous ferrotungstens, once these refractory alloys have been suitably opened out. An easy method of doing this is described by the author in "Technics," Vol. II, page 461, under the determination of tungsten. For present purposes, one quarter of a gram of the crushed specimen is treated with a few cubic centimeters of hydrofluoric acid, and strong nitric acid is then added in drops until no further action takes place. The whole mixture is then evaporated, after adding 2 cubic centimeters of strong sulphuric acid, to the complete expulsion of the more volatile acids as indicated by the appearance of sulphur trioxide fumes. The residue is then washed from the platinum dish or crucible into the flask and the assay carried forward. Fred Ibbotson, "Technics," February, 1905.

REVIEW OF THE IRON AND STEEL MARKET

The trade situation in iron and steel has been further strengthened since last report. The month of March was opened with several assuring events, including the advance of $2.00 per ton in merchant steel bars, the advance in Connellsville coke workers' wages of about 9 per cent, the purchase of 40,000 tons of pig iron by the steel corporation for March and the advance of a half point in merchant pipe.

The advance in coke worker's wages was particularly significant from the fact that the H. C. Frick Coke Company, which always leads in wage changes, had contemplated making this advance at the beginning of the year, but concluded to await absolute certainty that the present prosperity in the iron industry would be measurably permanent. A further influence was the necessity of retaining labor in the coke region, since the pressure for coke is such that all the available capacity must be kept in operation. Some advances in wages elsewhere in the iron industry are expected.

In the second half of the month the Pittsburg Steel Company, an interest operating a complete wire plant and a hoop plant and having allied with it a company just completing a seamless tube plant, made one of the largest purchases of billets ever recorded, buying about 192,000 tons of Bessemer and open-hearth billets for delivery during the twelve months beginning July 1 next, at a price a trifle above the regular "official" price, and not a great deal below the market which has ruled for small lots for early delivery. The transaction betokened the greatest faith in the market outlook on the part of the purchaser. The whole market has been further assured by this purchase.

Buying of pig iron has been fairly heavy during March, while new business in finished steel products has been rather light. In some lines, particularly wire and merchant pipe, heavier buying was expected ere this, but in general the situation in finished products is very satisfactory, since the mills are well sold up and have been able to operate to full capacity on specifications on old contracts. In several lines, and in partic-

ular in plates and merchant steel bars, new specifications received during the month have been greater than the month's output, so that the month ends with mills farther behind on deliveries than they were at its beginning.

On Saturday, March 4, Lake Superior ore shippers and vesselmen got together and informally agreed on a basis for season contracts for ore carriage down the lakes. The rates show an advance of 5 cents over last season, which the ore shippers had been willing to pay, while vesselmen had held out for an advance of 10 or 15 cents. The new rates are 75 cents from the head of the lakes, 70 cents from Marquette and 60 cents from Escanaba, to lower lake ports. Out of these rates the vesselmen pay the dock charges at the lower end of the haul of 19 cents. Contracts were signed the following week for a large tonnage, and by now almost 15,000,000 tons of ore movement have been contracted for. Interests owning or chartering vessels will move about as much more, so that but a little ore coming down "wild" would make the 30,000,000-ton movement for the season, which was at first predicted with diffidence, but is now quite assured, unless physical conditions prevent.

Pig Iron. — Sales were heavier during March than in the preceding month. Bessemer and basic iron have moved freely in the Pittsburg market, while basic has been well bought in the east. Sales of foundry iron have been fairly heavy all over the country and a new feature of the market is the appearance of the smaller foundry interests as confident buyers, the market earlier in the year having been almost monopolized by the larger buyers. The slight weakness noted in last report in foundry iron in the Pittsburg district has entirely disappeared, and that line is now very firm. Towards the close of February the United States Steel Corporation bought 40,000 tons of Bessemer for March delivery, following purchases of 25,000 tons each for December and January and 30,000 tons for February. The corporation is now buying 75,000 tons for equal deliveries over the second quarter, and some of its subsidiaries may take special lots of their own. The Cambria Steel Company has bought 35,000 tons of Bessemer and basic, all at the equivalent of $15.50, valley furnace, or $16.80, delivered Johnstown, for second quarter delivery, although a small portion has already been shipped. The Youngstown Iron Sheet and Tube Company bought 25,000

tons of Bessemer at $15.50, valley, for delivery over the second half, this to go to the Republic Iron and Steel Company on its old conversion contract involving some 6,000 tons of billets and skelp monthly, the Youngstown Iron Sheet and Tube Company making most of the iron for this deal at its Alice furnace. Various interests have taken smaller lots of Bessemer and basic, and before the close of the month the market showed a strongly advancing tendency, with the probability that a basis of $16.00, valley, will shortly be fully established. Foundry iron is firmer in all markets, and appears on the verge of a 25 or 50 cent advance, particularly in the south. Forge has not partaken of this greater strength. Prices are as follows: F.o.b. valley furnace: Bessemer, $15.50 to $16.00; basic, $15.50 to $15.75; No. 2 foundry, $16.00 to $16.50; forge, $15.00 to $15.25. At Pittsburg, Bessemer, $16.35 to $16.85; basic, $16.35 to $16.60; No. 2 foundry, $16.85 to $17.35; forge, $15.85 to $16.10. F.o.b. Birmingham: No. 2 foundry, $13.50 to $14.00; gray forge, $12.75 to $13.00. Delivered Philadelphia: No. 2 X foundry: $17.50 to $18.00; standard gray forge, $15.75 to $16.25; basic, $16.75 to $17.00. Delivered Chicago: Northern No. 2 foundry, $17.50; southern No. 2 foundry, $17.15 to $17.65; malleable Bessemer, $17.50.

Steel. — One of the largest billet purchases in the history of the trade was that by which the Pittsburg Steel Company bought 72,000 tons of Bessemer billets from the Republic Iron and Steel Company and 120,000 tons of open-hearth billets from the Carnegie Steel Company, for equal deliveries over the twelve months beginning with next July, making 6,000 tons of Bessemer and 10,000 tons of open-hearth per month. The exact price is kept a secret but it is a fairly safe assumption that it is a trifle above the "official" price, with a strict guaranty against decline. The official price is $21.00, f.o.b. Pittsburg, which makes a price delivered Monessen, where the bulk of the steel will be used, of $21.45. Otherwise, sales of billets have been confined to small lots for early shipment, and on these mills are securing premiums of from $2.50 to $3.00 on billets, and $3.00 to $3.50 on sheet bars. The official prices, f.o.b. Pittsburg, are $21.00 on ordinary soft steel billets, 4 × 4 and larger, and $23.00 on small billets, forging billets and sheet bars, long lengths, with 50 cents extra for shearing sheet bars to specifications.

Shapes. — Little new business has been done, large consumers having covered with season contracts before the advance of February 16. Structural contracts are being placed a little more freely, but there is still some hesitation, and mills are not in receipt of specifications beyond their capacity. Official prices are: Beams and channels, 15-inch and under, angles 2 x 3 to 6 x 6 inclusive and zees, 1.60 cents; tees, 3-inch and larger, 1.65 cents; beams and channels over 15-inch, 1.70 cents. Sizes under 3-inch are classified as merchant bars.

Plates. — Many of the plate mills are from four to six weeks behind on specifications, and on very small lots occasional premiums are paid for immediate shipment. The rush arises almost wholly from specifications on contracts made before the advance of February 16. Prices are 1.50 cents for 6¼ to 14 inches wide and 1.60 cents for widths over 14 inches and not over 100 inches, f.o.b. Pittsburg, carload and larger lots, tank quality, quarter-inch and heavier, with the usual extras for thinner plates, extreme widths and special quality.

Merchant Bars. — In steel bars mills are a month or more behind on specifications in some cases. In iron bars the market is fairly strong. The official price on steel bars is 1.50 cents, for either Bessemer or open-hearth. Iron bars are fairly firm, common bars of recognized quality being quoted at 1.65 cents, f.o.b. Youngstown. For western delivery the full freight differential is not maintained.

Sheets. — Effective March 16 the following advances were announced by the leading interest, and followed by the independents: Black sheets, one pass cold rolled, $2.00 per ton; Wood's refined iron, $2.00 per ton; blue annealed sheets, $1.00 per ton; painted corrugated roofing, 10 cents per square. New business has been light, but mills continue busy on old orders. Prices in carload and larger lots are: No. 28 gauge, black, 2.40 cents; galvanized, 3.45 cents; corrugated roofing, 28 gauge, painted, $1.75 per square; galvanized, $2.95 per square, all f.o.b. Pittsburg.

Scrap. — The market is firmer, the supply being very limited. There is rather spirited bidding on all lots that come out, and no large sales Prices are about as follows in the Pittsburg market: Heavy melting stock, $16.50 to $17.00; cast scrap, $15.00 to $15.50; sheet scrap, $15.00 to $15.50; cast borings, $10.75 to $11.00.

STATISTICS

Production of Bessemer Steel Ingots and Rails in 1904. — We present below virtually complete statistics of the production of Bessemer steel ingots and castings in the United States in 1904; also of Bessemer steel rails rolled by the producers of Bessemer steel ingots.

Ingots and Castings. — The total production of Bessemer steel ingots and castings in 1904 was 7,859,140 gross tons, against 8,592,829 tons in 1903, a decrease of 733,689 tons, or over 8.5 per cent. The production in 1902 was the largest in our history,— 9,138,363 tons.

The following table gives the production of Bessemer steel ingots and castings in the last six years. Of the production last year 16,051 tons were steel castings, against 18,099 tons in 1903.

Years Gross tons	Ingots and castings	Years Gross tons	Ingots and castings
1899	7,586,354	1902	9,138,363
1900	6,684,770	1903	8,592,829
1901	8,713,302	1904	7,859,140

Below we give by states the production of Bessemer ingots and castings in the last four years.

States — Ingots and castings	1901 Gross tons	1902 Gross tons	1903 Gross tons	1904 Gross tons
Pennsylvania . .	4,293,439	4,209,326	3,909,436	3,464,650
Ohio	2,154,846	2,528,802	2,330,134	2,050,115
Illinois	1,324,217	1,443,614	1,366,569	1,257,190
Other states . .	940,800	956,621	986,690	1,087,185
Total	8,713,302	9,138,363	8,592,829	7,859,140

There were no Clapp-Griffiths works in operation in 1904 and only 2 Robert-Bessemer plants were active. Eleven Tro-

penas plants were at work, as compared with 8 in 1903. In addition, 2 plants made steel by the Bookwalter process and 5 plants made steel in special Bessemer converters. All these active works make a specialty of steel castings.

Rails. — The production of all kinds of Bessemer steel rails by the makers of Bessemer steel ingots in 1904 was 2,084,438 gross tons, against a similar production in 1903 of 2,873,228 tons. The production in 1904 was 788,790 tons less than in 1903. The maximum production of Bessemer steel rails by makers of Bessemer ingots was reached in 1902, when 2,876,293 tons were made.

The following table gives the production by states of Bessemer steel rails by the producers of Bessemer steel ingots in the last four years. Included in the figures for 1904 are 11,901 tons of renewed rails rolled by mills operated by companies which manufacture Bessemer ingots.

States — Rails	1901 Gross tons	1902 Gross tons	1903 Gross tons	1904 Gross tons
Pennsylvania .	1,406,008	1,148,425	1,185,191	801,657
Other states . . .	1,430,265	1,727,868	1,688,037	1,282,781
Total	2,836,273	2,876,293	2,873,228	2,084,438

In the following table we separate the production of rails weighing 45 pounds and less than 85 pounds to the yard from those weighing less than 45 pounds and over 85 pounds to the yard. Bessemer rails made from purchased ingots or from rerolled rails by companies which do not manufacture Bessemer ingots are *not included.*

States — Rails Gross tons	Under 45 pounds	45 pounds and less than 85	85 pounds and over	Total Gross tons
Pennsylvania .	127,136	438,669	235,852	801,657
Other states . . .	103,630	751,962	427,189	1,282,781
Total for 1904	230,766	1,190,631	663,041	2,084,438
Total for 1903	178,146	1,529,580	1,165,502	2,873,228

The total production of rails in 1904 will include rails made from open-hearth steel, rails rolled from purchased Bessemer blooms, crop ends and "seconds," and rails rerolled or renewed by non-producers of Bessemer steel ingots and iron rails. The total from all these sources in 1903 amounted to 119,249 tons, of which quantity 45,054 tons were open-hearth steel rails and only 667 tons were iron rails. In 1904 the total from these sources will amount to about 200,000 tons, making the total rail production for that year about 2,300,000 tons.

In 1904 this country exported 414,845 tons of steel rails and 1,405 tons of iron rails, and imported 37,776 tons of iron and steel rails. "The Bulletin," American Iron and Steel Association, February 15, 1905.

Foreign Iron and Steel Trade. — The value of the iron and steel exported from the United States during the full year 1904 is estimated by the Bureau of Statistics at $128,553,613. As compared with $99,135,865 for 1903, this shows an increase of $29,417,748 over the previous year. These figures cover not only raw materials, except ore, but also rolled products, engines, machinery and tools.

The amounts, in long tons, of the leading items for the two years stand as follows:

	1903	1904	Changes
Pig iron	20,379	79,025	I. 58,646
Bars	59,543	75,549	I. 16,006
Rails	31,137	416,250	I. 385,113
Structural steel	30,641	55,514	I. 24,873
Wire	108,521	118,581	I. 10,060
Nails and spikes	42,644	45,108	I. 2,464

The tremendous increase in the exports of steel rails will be noticed. The heaviest shipments, 216,801 tons, went to Canada; Japan and Asia received 101,738 tons; South America, 28,347 tons; and Mexico, 23,871 tons. Shipments to all of Europe amounted to only 17,581 tons.

Imports of iron and steel, and their manufactured products, during 1904 were valued at $21,621,970, showing a decrease of $19,633,894 from their valuation in 1903. The principal items, in long tons:

	1903	1904	Changes
Pig iron	599,574	59,500	D. 540,074
Billets, blooms, etc.	261,570	10,801	D. 250,769
Scrap iron and steel	82,921	13,461	D. 69,460
Bars	43,393	20,912	D. 22,481
Rails	95,555	37,776	D. 57,779
Wire-rods	20,836	15,313	D. 5,523
Tin-plates	47,360	70,652	I. 22,292

The movement of iron ore between this and other countries during the same period is shown by the following:

	1903	1904	Changes
Exports	80,611	213,865	I. 133,254
Imports	980,440	487,613	D. 492,827
Excess of imports over exports	899,829	273,748	D. 626,081

Imports came mainly from Cuba. Exports consist principally of Michigan ores, that are shipped to Midland and Hamilton, Ontario. "Engineering and Mining Journal," February 9, 1905.

Production of Pig Iron in Canada in 1904. — The American Iron and Steel Association has received direct from the manufacturers the statistics of the production of all kinds of pig iron in Canada in the calendar year 1904. They show an increase of 5,524 gross tons, or a little over 2 per cent, as compared with 1903, but a decrease of 48,615 tons as compared with 1902.

The total production in 1904 amounted to 270,942 gross tons, against 265,418 tons in 1903, 319,557 tons in 1902, 244,976 tons in 1901 and 86,090 tons in 1900. In the first half of 1904 the production was 120,643 tons and in the second half it was 150,299 tons, an increase of 29,656 tons. Of the total production in 1904, 251,671 tons were made with coke and 19,271 tons with charcoal. About one fourth of the total production was basic pig iron, namely, 70,133 tons. The production of Bessemer pig iron, all made in the last half of the year, was 26,016 tons. Spiegeleisen and ferromanganese have not been made since 1899.

The following table gives the total production of all kinds of pig iron (including spiegeleisen and ferromanganese) in Canada

from 1894 to 1904. Prior to 1894 the statistics of pig-iron production in Canada were not collected by this Association.

Years	Gross tons	Years	Gross tons	Years	Gross tons
1894......	44,791	1898....	68,755	1902....	319,557
1895......	37,829	1899....	94,077	1903....	265,418
1896.....	60,030	1900....	86,090	1904....	270,942
1897......	53,796	1901....	244,976	....	....

The unsold stocks of pig iron in Canada on December 13, 1904, amounted to 35,119 tons.

On December 31, 1904, Canada had 15 completed blast furnaces, of which 8 were in blast and 7 were idle. Of this total, 10 were equipped to use coke for fuel and 5 to use charcoal. In addition, 3 coke furnaces were partly erected on December 31, but work on the furnaces had been suspended some time ago. "The Bulletin," American Iron and Steel Association, March 1, 1905.

German Iron Production. — The iron industry of Germany was almost stationary last year, so far as the production of pig iron was concerned. In 1903 there was a gain over the previous year of 1,683,974 tons, or 20 per cent; last year, the increase over 1903 was only 18,307 tons, or 0.2 per cent. There were, however, considerable changes in the proportions of the different kinds of iron, as shown in the following table:

	1903		1904	
	Tons	Per ct.	Tons	Per ct.
Foundry iron	1,798,773	17.8	1,865,599	18.5
Forge iron	859,253	8.5	819,239	8.1
Steel pig	703,130	7.0	636,350	6.3
Bessemer pig	446,701	4.4	392,706	3.9
Thomas (basic) pig ...	6,277,777	62.3	6,390,047	63.2
Total	10,085,634	100.0	10,103,941	100.0

Steel pig, in the German classification, includes spiegeleisen, ferromanganese, ferrosilicon and all similar alloys. It will be seen that forge iron and Bessemer pig showed considerable decreases, the gains in foundry and basic irons keeping up the total. The German practice runs each year more to the use of the basic

converter in putting the iron into final form. No other iron-making nation converts so large a proportion of its pig into steel, or makes so little use of the puddling furnace. The United States comes nearest to Germany in this respect, but uses, in proportion, more cast iron.

The Rhenish-Westphalian district is the largest producer, making last year 39.8 per cent of the total; while Lorraine and Luxemburg came next, with 32.3 per cent, Silesia supplied 8.2 and the Saarbezirk 7.5 per cent. The Rhenish-Westphalian furnaces are the largest makers of both foundry and Thomas pig, while Silesia is the chief source of forge iron.

The making of this iron required the consumption of over 30,000,000 tons of iron ore. The great majority of the German furnaces use ore having 35 per cent iron or less. The extra cost of fuel and handling with low-grade ores finds compensation partly in the fact that much of the ore is self-fluxing; but more in the attention given to by-products of the furnaces and to saving in every possible direction. "The Engineering and Mining Journal," February 16, 1905.

RECENT PUBLICATIONS

Lehrbuch der mechanisch-metallurgischen Technologie, Erste Abteilung, by A. Ledebur. 400 4×6-in. pages; over 400 illustrations. Paper covers. Friedrich Vieweg & Sohn, Braunschweig, Germany. 1905. Price, $4.25. — This is the first volume of the third edition of Professor Ledebur's "Mechanical Metallurgy." It is a companion volume of the author's well-known "Chemical Metallurgy." As the title suggests, Professor Ledebur deals with the mechanical side of the metallurgical art, and the complete work will not only include iron and steel, but the other important industrial metals as well. In this first volume the author describes chiefly rolls and hammers. As might be expected, the treatment represents European rather than American practice. The book is finely printed and illustrated.

Report of the Commission Appointed to Investigate the Different Electro-thermic Processes for the Smelting of Iron Ores and the Making of Steel, in Operation in Europe, by Eugene Haanel, commissioner, Ottawa, Canada. 224 7×10-in. pages; many illustrations and folding tables. — Discussions and abstracts of this important report have appeared in several issues of *The Iron and Steel Magazine*, and our readers are familiar with its contents. The present publication comprises, (1) the report of the commission appointed to investigate the electro-thermic processes for the smelting of iron ores and the making of steel, now in operation in Europe; (2) the report of a special commission appointed to investigate the Marcus Ruthenburg process of electric smelting of magnetite; and (3) an appendix containing a series of important papers on the subject of electro-metallurgy of steel and iron, by Harmet, Gin and Stassano; and of copper by Vattier. The beautiful illustrations add much to the interest and value of this publication.

Techno-Chemical Analysis, by Dr. C. Lunge. Translated from the German by Alfred I. Cohn. 144 5×7-in. pages; illus-

trated. John Wiley & Sons, New York. 1905. Price, $1.00. — This English translation of Dr. Lunge's extremely useful book should be warmly welcomed by analytical chemists. It is not an exhaustive treatise of analytical methods, but rather a collection of practical notes for the laboratory worker. The first part deals with the sampling and preparation of the substance to be analyzed, with technical gas analysis and gas-volumetry, while in a second special part the author treats briefly of the analysis of fuels, water and of many compounds of inorganic chemical manufacture, of tar, oils, soap, sugar, alcohol, wine, beer, etc. The conciseness and clearness of the treatment should appeal strongly to the busy commercial analyst. The book is very nicely printed and bound.

The Journal of the Iron and Steel Institute. Vol. LXVI (No. II, 1904). Edited by Bennett H. Brough, secretary. 711, $4\frac{1}{2} \times 8$-in. pages; illustrated. E. & F. N. Spon, London. 1905. — This volume includes the minutes of the autumn meeting held in New York, October 24, 25 and 26, 1904, and the usual valuable "Notes on the Progress of the Home and Foreign Iron and Steel Industries." The following papers were read and discussed at the New York meeting:

"The Influence of Carbon, Phosphorus, Manganese and Sulphur on the Tensile Strength of Open-Hearth Steel," by H. H. Campbell.

"Mining and Metallurgy at the St. Louis Exposition," by H. Bauerman.

"A West African Smelting House," by C. V. Bellamy.

"The Development and Use of High-Speed Tool Steel," by J. M. Gledhill.

"The Utilization of Exhaust Steam, from Engines Acting Intermittently by Means of Regenerative Steam Accumulators and of Low-Pressure Turbines on the Rateau System," by E. Demenge.

"Acid Open-Hearth Manipulation," by A. McWilliam and W. H. Hatfield.

"Methods for the Determination of Carbon and Phosphorus in Steel," by Baron H. von Juptner, A. A. Blair, G. Dillner and J. E. Stead.

"The Application of Dry-Air Blast to the Manufacture of Iron," by J. Gayley.

This volume also contains a full report of the visits and excursions of the American meeting as well as a reprint of the paper, by F. L. Grammer, "On a Decade in American Blast-Furnace Practice," read before the American Institute of Mining Engineers, and a reprint of B. E. V. Luty's excellent article "Changes in the American Iron Industry since the Iron and Steel Institute Meeting of 1890," published originally in "The Iron Trade Review."

A recent photograph of Sir Lowthian Bell, Bart., who died on December 21, 1904, is reproduced as a frontispiece.

Modern Industrial Progress, by Charles H. Cochrane. 647, 6×9-in. pages; over 400 illustrations. J. B. Lippincott Company, Philadelphia and London. 1904. Price, $3.00. — Although written primarily for the general reader, this book should prove of much interest also to the engineer and scientist. In its pages will be found described and profusely illustrated the wonderful industrial progress of the last decade. While such a book cannot possibly be exhaustive, most of the modern wonders of applied science are here presented to the reader in a very attractive and instructive manner. The reader is taken on an excursion through a real wonderland, where he is shown the electrical marvels of the last decade, the kingdom of iron and steel, the conquests of the air, the evolution of automobiles, the building of battleships, the manufacture of guns, projectiles and other tools of destruction, the construction of some great canals and tunnels, great farms and farming machinery, the iron horse and the railways, the light of to-day and of to-morrow, the logging-camp and the transportation of the logs to the planing-mill, the bowels of the earth, modern foods and food preservation, water works, printing presses, the making of newspapers and periodicals, the manufacture of paper, the telescopes and other wonderful instruments of science, the building of bridges, the machinery of amusement, how money is manufactured, machine tools and machine making, engines and progress in power producers, textile manufactures, glass making, modern architecture, flour milling by modern machinery, leather and

shoe machinery, and many other marvels pertaining to miscellaneous industries. The book is beautifully printed and illustrated and attractively and substantially bound.

Lecons sur l'Électricité Professées à l'Institut Électro-technique Montéfiore, annexé à l'Université de Liége, by Eric Gérard. Vol. II. *Transformations, canalisations et distributions de l'énergie électrique, applications de l'électricité, à la télégraphie, à la téléphonie, à l'éclairage, à la production et à la transmission de la puissance motrice, à la traction, à la Métallurgie et à la Chimie industrielle.* Seventh edition. 888 $5\frac{1}{2}\times10$-in. pages; 432 illustrations. Paper covers. Librarie Gauthiers-Villars, Paris. 1905. Price in France, 12 francs. — The first volume of this important work was reviewed in our issue for October, 1904. The author, who is director of the Montéfiore Electro-technique Institut at Liége (Belgium), is one of the most eminent electrical experts and his presentation of the subjects treated in his book bears the stamp of his authority.

Conversation on Chemistry, by W. Ostwald, professor of chemistry in the University of Leipzig. Authorized translation by Elizabeth Catherine Ramsay. Part I, General Chemistry. 250 5×7-in. pages; 46 illustrations. John Wiley & Sons, New York. 1905. Price, $1.50. — This English translation of Professor Ostwald's exceedingly interesting and instructive book will not fail to be welcomed by many students of chemistry. The clear, logical and almost fascinating manner with which the author leads us through the elementary principles of chemistry makes the reading of this book a recreation rather than a study. The translator is to be congratulated upon her excellent and faithful version. We cannot commend the selection of the publishers of a white lettering for the inscription on the back and front cover. It is much less satisfactory than the usual gold inscription. The second part, which is in preparation, will deal with the chemistry of the most important elements and compounds.

Applied Mechanics, by Andrew Jamieson. Sixth edition, revised and enlarged. 345 $4\frac{1}{2}\times7\frac{1}{2}$-in. pages; numerous illustrations. Charles Griffin & Co, Limited, London. 1904. Price,

3*s*. 6*d*. — This book is especially arranged for first-year engineering students, and includes many carefully selected examination questions. The fact that it has reached its sixth edition is an evidence of its popularity.

The Architect's Directory and Specifications Index. Edition of 1904–1905. 160 7×10-in. pages. William T. Comstock, New York, 1904. Price, $2.00. — This is the sixth edition of the Architect's Directory. It gives the names and addresses of architects in the United States and Canada, including landscape architects, a list of architectural societies, a specification index of many manufacturers and dealers in building material. A new schedule of charges of the American Institute of Architects is appended to this issue. The many advertising displays which are carelessly scattered through the directory proper somewhat mar its appearance and reduce its value as a ready reference book.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

780,026. Gas-Producing Apparatus. — Robert S. Craig, Chicago, Ill. In a gas-producing apparatus, a combustion-chamber, a carbonaceous-material supply communicating therewith, a fixing-chamber, communicating at its top with said combustion-chamber, a second fixing-chamber communicating at its bottom with the bottom of the first-mentioned fixing-chamber, a receptacle having a pair of compartments, one of which forms a vaporizing-chamber and the other of which a condensing-chamber, said vaporizing-chamber provided with a water-inlet and said condensing chamber with an air inlet and outlet, said receptacle further provided with a water-outlet, means for establishing communication between the top of said second mentioned fixing-chamber and top of said receptacle, a vaporizing coil extending in said vaporizing chamber and communicating with a hydrocarbon supply, said coil further communicating with the top of said combustion chamber, a wash box communicating with said receptacle, and an air pipe communicating at one end with the air outlet of said condensing chamber and at its other end with the combustion chamber below the fuel therein.

780,090. Gas Producer. — William J. Crossley and Thomas Rigby, Manchester, England. In combination a vertical cylinder of but half the diameter of the producer mounted concentrically within the producer on a concrete bed or other suitable foundation, a ball-race on the top of the cylinder, a rotary conical perforated fire grate mounted on the ball-race, horizontal pipes for the supply of air and steam to the interior of the cylinder, bevel teeth on the base plate of the cone, and a bevel pinion gearing therewith and fixed on a shaft passing along one of the horizontal air pipes and terminating outside the producer.

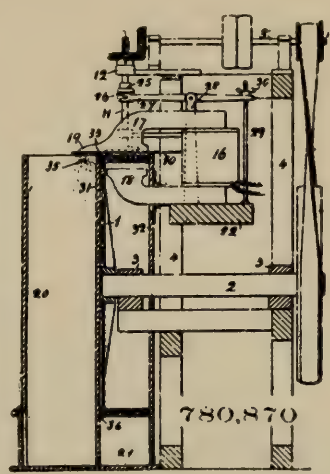
780,349. Method of Treating Molding-Sand. — Frank E. Johnson, Greensburg, Pa., assignor to John T. Kelly, Brooklyn, N. Y., and George M. Jones, Pittsburg, Pa. The method of treating molding-sand, which consists in taking the sand after having been used in a mold, reducing the same to a fine condition, tempering the same either before or after reducing, and then returning the same to the molds to be re-used.

780,579. Releasing Device for Rolling-Mill Rolls. — John L. Rehnstrom, McKeesport, Pa. A combination consisting of a base having an integral tapering shank, a keyway formed through said shank, inclined

top, a longitudinally divided sectional cylindrical portion, the base of which corresponds to the inclined top of said shank, a ring of weaker material surrounding said sectional portion, having a tapering bore and engaging with the shank, and a tapering key arranged to bear upon the under side of said ring.

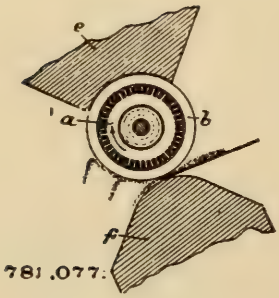
780,716. METHOD OF AGGLOMERATING MAGNETIC ORE. — Elmer Gates, Chevy Chase, Md., assignor to Theodore J. Mayer, Washington, D. C. A method of agglomorating magnetic sand, which consists in establishing an electric arc between opposing surfaces, feeding opposing streams of sand over said surfaces, and causing said streams of sand to fall freely from said surfaces so as to break the arc originally formed and establish arcing from one of the falling streams to the other, thereby fusing and agglomerating the sand into small lumps of a size varying substantially from that of a wheat grain to that of a bean.

780,870. MAGNETIC SEPARATOR FOR ORES OR SIMILAR MATERIALS. — John T. Dawes, Liverpool, England. In a magnetic separator the combination of a moving conveyor for receiving the material, a second moving conveyor above the first moving conveyor, a magnet pole above the second moving conveyor, and a shield disposed under the second moving conveyor between the outer extremity of the magnet pole and the first moving conveyor and parallel to and in contact with the side of the first moving conveyor, part of the top of the shield under the magnet pole being level with the first moving conveyor.



780,873. WIRE-NAIL MACHINE. — Joseph F. Donaghy, Coraopolis, Pa., assignor of one third to Edward H. Foreman, Shousetown, Pa. A wire-nail machine having in combination gripping dies, wire-feed mechanism, a guide-passage for directing the wire to said dies, means for shearing said wire within the limits of the guide-passages.

780,911. BLOWING-ENGINE OR COMPRESSOR. — Gustav B. Petsche, Philadelphia, Pa., assignor to Southwark Foundry and Machine Company, Philadelphia, Pa. As a device for actuating the delivery-valve of a blowing-engine or compressor, a cylinder, having guideways for a slide extending transversely through its walls, in combination with a conduit, connecting the inner end of the cylinder with the compressing-cylinder, a regulated escape-passage for air connecting with the rear end of the cylinder, pistons working in the inner end and outer ends of the cylinder, said pistons being connected together and with the stem of the delivery-valve, a reciprocating slide working through the guideways on the cylinder and between the pistons, and means actuated by said slide for moving the pistons toward the inner end of the cylinder when the slide moves in one direction and leaving them free to move toward the outer end of the cylinder when the slide moves in the other direction.



781,077. Electro-Magnetic Ore Separator. — Erich Langguth, Euskirchen, Germany. In a magnetic separator, the combination with pole-pieces of an armature rotating between said pole-pieces and having windings, a shield of magnetic material mounted directly on said armature and rotating therewith, means for feeding the material to be separated to said armature, and means for collecting the separated material.

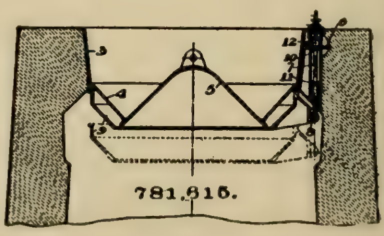
781,078. Art or Process of Removing Scale from Wires, Rods, Etc. — Archibald B. Legnard, Waukegan, Ill. A method of removing scale from wires or rods consisting in coiling the same around a roll of small diameter as it passes continuously from one spool or reel to another and thereby subjecting it to short, sharp bendings and crinkling and loosening the scale from the surface of the wire or rod.

781,150. Furnace-Charging Apparatus. — Edward W. Lindquist, Chicago, Ill., assignor to Ralph Baggaley, Pittsburg, Pa. The combination of a furnace having a charge-receiving opening, a conveyor discharging into said opening, and means for reciprocating the conveyor along the opening during the delivery of the charge, said opening being of greater width than the delivery end of the conveyor.

781,230. Method of Coating Metals. — Hugh Rodman, Cleveland, O. A method of coating a metal which consists in subjecting it to the action of a molten coating metal, and maintaining in said coating metal a suitable proportion of an alkali metal.

781,293. Cinder-Ladle. — Thomas McDonald, Youngstown, O. A cinder-ladle consisting of an outer ladle, an inner thimble so supported that its bottom is not in contact with the ladle, the space between bottoms of ladle and thimble packed with a refractory material, a removable bottom for the thimble, and having means not in contact with the outer ladle for securing the removable bottom to the thimble.

781,300. Manufacture of Metallic Alloys. — Thomas Prescott, Huddersfield, England, A method of making metallic alloy for casting, which consists in melting a quantity of iron, adding aluminum and zinc to the molten iron, thoroughly melting and alloying the mixture, and finally adding silicon.



781,615. Blast-Furnace-Charging Apparatus.— Thomas McDonald, Youngstown, O. In blast-furnace-charging apparatus, a hopper, a bell arranged to close the same, a deflector-ring outside of the bell and independent of its movements, and means for vertically adjusting the ring independently of the bell.

781,688. Electric Ingot-Extractor. — James R. Speer and Willie H. Baltzell, Pittsburg, Pa. In an ingot-stripper, a traveling crane, a screw-threaded mechanism carried thereon, means on the crane for rotating the screw-threaded mechanism, said means being arranged in

such a manner as to cause, by the rotation of said screw-threaded mechanism, relative longitudinal movement of the mold and ingot and means for maintaining the rotating means in operative relation to the screw-threaded mechanism during the working movements of the latter.

781,708. INGOT-STRIPPER. — Willie H. Baltzell, Pittsburg, Pa. In an ingot-stripper, a mold-engaging device, a carrier therefor, an ingot-stop, a carrier therefor, sheaves supported by the carriers, a flexible device on the sheaves and means for operating the flexible device.

781,760. APPARATUS FOR ROLLING BARS FROM COILS. — John Bergmann, Pittsburg, Pa. In apparatus for rerolling coiled springs, the combination of rolls and housings therefor, and a spring-support arranged to hold the coiled spring so that it can rotate, said spring-support being located at one side of the plane in which the axes of the rolls lie and being movable toward and from said plane.

781,808. PROCESS OF REDUCING VANADIUM. — Franklin R. Carpenter, Denver, Col. A process of extracting vanadium from siliceous ores containing it which consists in subjecting a furnace charge comprising the siliceous ore of vanadium, a compound of a carrying metal with which vanadium will alloy, a basic flux and fuel, to an air-blast, the fuel and blast being proportioned to each other and to the other ingredients of the charge, to maintain a high temperature and reducing action, thereby causing a reduction of the vanadium and the carrying metal and the alloying of the two, and a union of the basic flux and the silica to form a slag.

781,887. APPARATUS FOR THE REMOVAL AND UTILIZATION OF SLAG. — Thomas C. King, Marion, Ala., assignor of six tenths to James W. McClure, Pittsburg, Pa. In an apparatus of the class described, the combination with the cinder-runs of a furnace or other source of molten-slag supply, of a slag-pit having a covered top with a steam-outlet therein and means to govern it, means to supply water to the pit at or about the point where the molten slag enters the pit, a water-overflow therein, a series of piping arranged within the upper portion of the pit, with inlet and outlet tubular connections leading to the exterior of the pit; and means to discharge the granulated slag from the pit.

782,082. ROTARY PUDDLING OR BUSHELING FURNACE. — William Stubblebine, Bethlehem, Pa. A rotary puddling, busheling or scrapping furnace having a treating vessel mounted so as to rotate about its longitudinal axis, said axis being inclined in respect to the horizontal, and said vessel having a gas-inlet at one end and a gas-outlet at the other, the gas-inlet being uppermost and being of greater area than the gas-outlet.

GREAT BRITAIN

28,590 of 1903. COATING IRON WITH COPPER. — S. Cowper Coles, London. Coating iron articles with copper, by heating them in intimate contact with finely divided cuprous oxide.

27,298 of 1903. MAGNETIC SEPARATOR. — J. T. Dawes, Flint. Improved magnetic separator consisting of two traveling belts one above

the other, the magnetic particles being attracted by means of a top magnet from the upper surface of the lower belt to the lower surface of the upper belt.

20,561 of 1904. BLAST-FURNACE CHARGER. — W. Lahmeyer & Co., Frankfort-on-Main, Germany. Improved apparatus for elevating cars full of ores, etc., to the top of blast furnaces.

23,331 of 1904. HARDENING STEEL. — A. de Diron and G. Bouton, Paris, France. The manufacture of steel articles with very hard surfaces by cementing chrome-nickel steel without subsequent hardening by quenching.

4,433 of 1904. REFRACTORY BRICK. — L. Williams and H. Tomkins, Stockton-on-Tees. In producing refractory bricks of siliceous matter, the use of magnesite as the binding materials instead of lime.

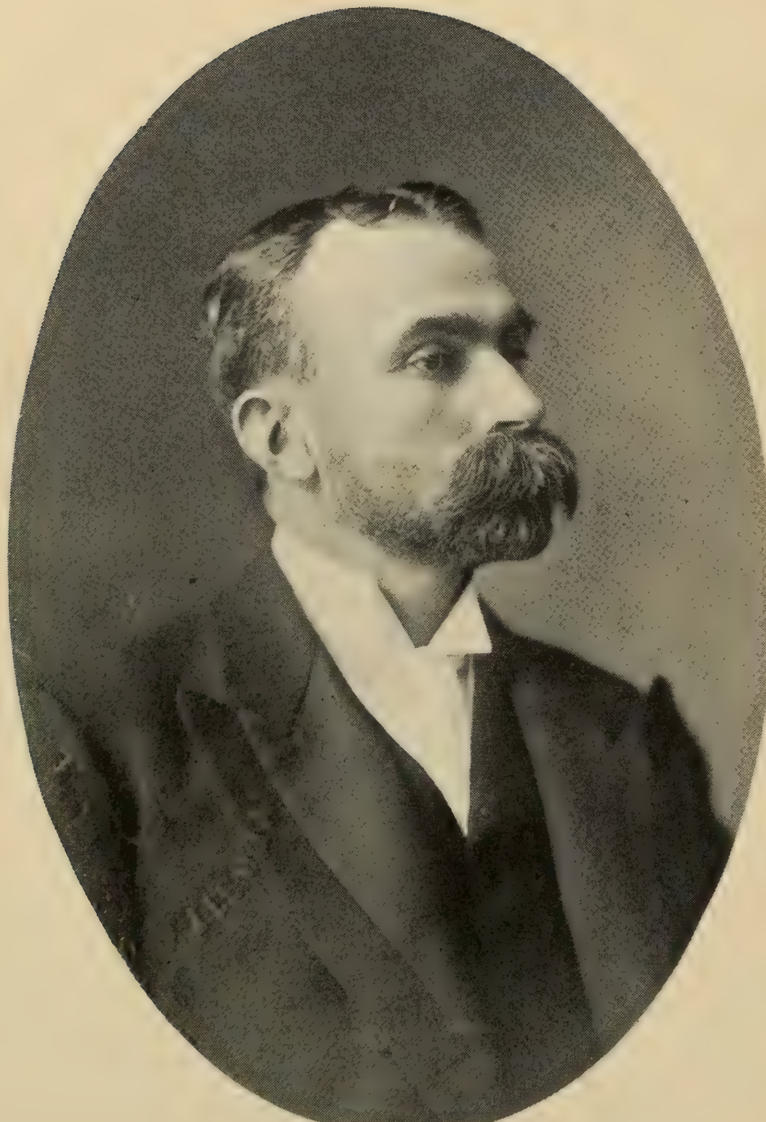
7,367 of 1904. SMELTING FURNACE. — O. Simmersbach, Crefeld, Germany. A furnace in which iron ores are smelted by carbon monoxide without any solid fuel or air.

28,602 of 1903. BASIC FURNACE LININGS. — H. Fas, Paris, France. Improved kiln for use in making basic linings for metallurgical furnaces.

28,736 of 1903. NICKEL STEEL. — T. H. Gannon and W. H. Phillips, Oldham, The use of a soluble nickel salt, such as nickel ammonia sulphate, for toughening steel.

13,892 of 1904. REMOVING MOISTURE FROM BLAST. — J. Gayley, New York. Refrigerating apparatus for removing moisture from air before use as blast in smelting furnaces.

23,380 of 1904. TREATING NICKEL ORES. — Société Electro-Metallurgique Francaise, Froges, France. Treating nickel ores free from sulphur in an electric furnace, and so obtaining an alloy of nickel cobalt and iron that can be used in the manufacture of nickel steel.



DAVID BAKER

SEE PAGE 465

The Iron and Steel Magazine

". . . . . . *Je veux au mond publier d'une plume de fer sur un papier d'acier.*"

Vol. IX | May, 1905 | No. 5

AN IMPROVEMENT IN COOLING JACKETS FOR BLAST FURNACES *

By DAVID BAKER

Special Contributor to The Iron and Steel Magazine

THE merits of the water cooled steel bosh jacket are sufficiently well known to metallurgists to make further discussion here unnecessary, but the comparative value of this form of protection and that offered by cooling plates, built in the wall of blast furnaces, especially when such protection is applied to the bosh wall of an iron blast furnace, is still an undecided question.

The plate jacket is much the older device, but was for a time after the advent of the Gayley and Scott bronze bosh plate nearly forgotten, due to the great popularity of the latter devices. In the last few years, however, there has been a notable tendency in certain districts to return to the external cooling system, in some form of plate cooling jacket, particularly for the bosh of the blast furnace.

Many modern stacks are now equipped with a combination of the two systems in this way: bronze internal plates from the tuyères to a point 5 or 6 feet above and then the plate jacket from there up to the top of the bosh.

The two systems of cooling call for quite different wall construction. In the case of the jacket, the cooling being entirely external, the wall is necessarily made thin, for any excess

* Received April 18, 1905.

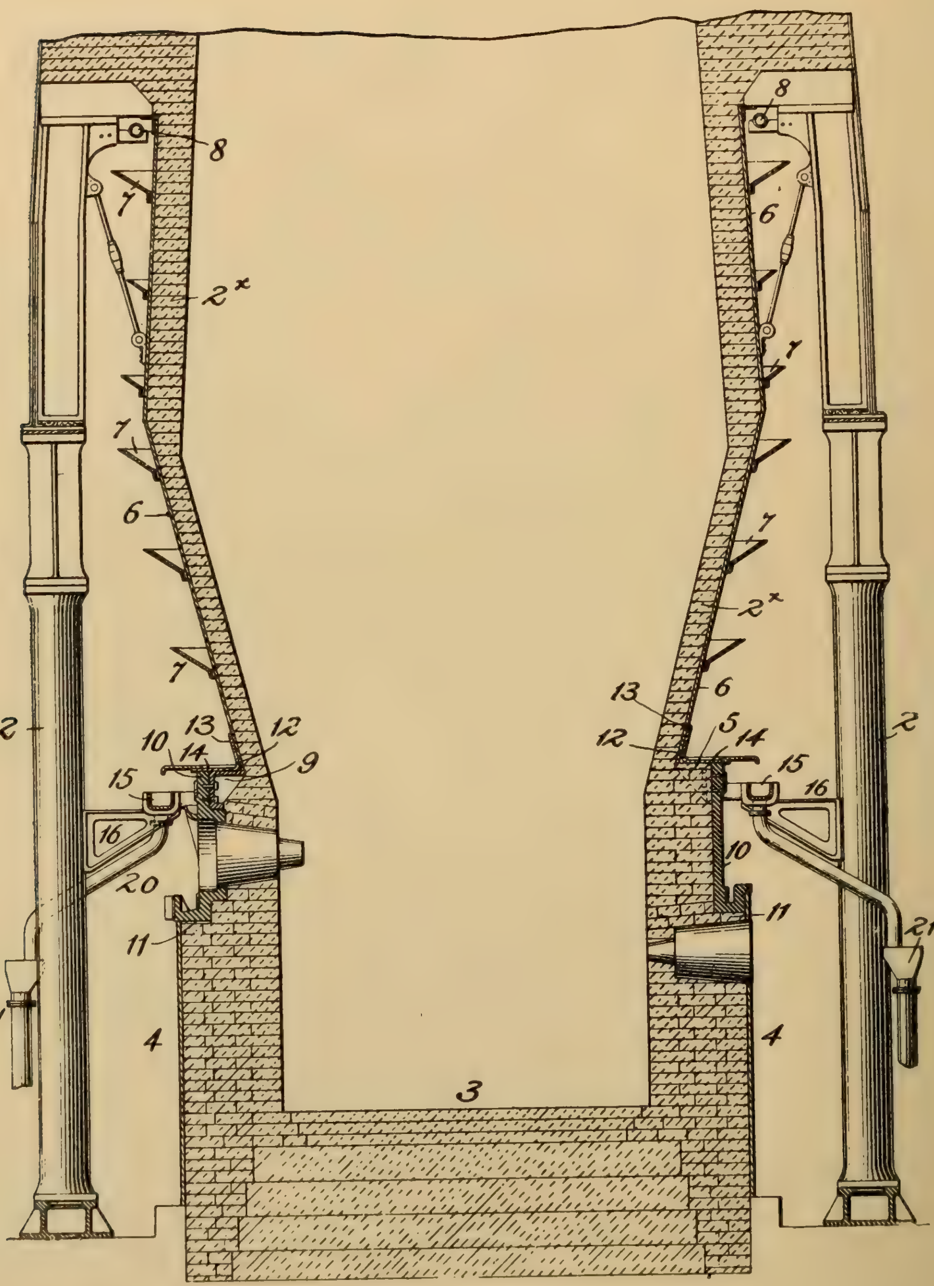

8
7
2x
7
6
7
2
13
12
10
14
9
15
16
20
11
21
4
3
8
6
7
7
2x
6
13
12
5
14
15
16
2
10
11
21
4

Fig. 1

above what is protected by the cooling on the outside would simply melt away the first week of the blast, but with the bosh plate, in order to insure sufficient strength, the walls are made heavier and the plates are laid close to the inner surface, this heavier construction being necessary on account of the binding usually used and adapted for that construction, that is, the wrought iron or steel band.

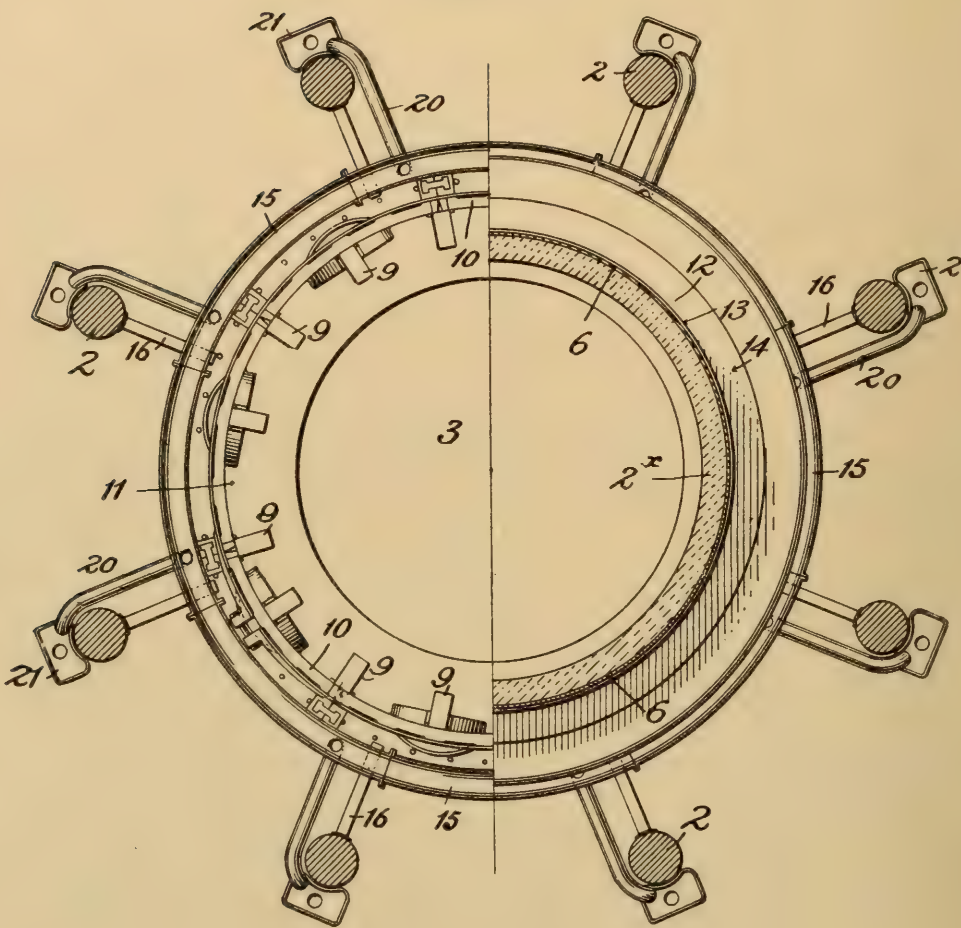
It is claimed by those using the water cooled jacket that it is cheaper construction, absolutely safe, easy to maintain, and gives a smooth wall on the inside of the furnace, thus contributing greatly to the regular working of the smelting operation. On the other hand, those of the other school claim that the bronze bosh plate saves fuel, and, with proper wall construction, is entirely safe.

To the question of fuel economy, those adhering to the jacket system of cooling make reply, that the whole matter resolves itself to that of cost of production, and that any slight gain made by saving of fuel when using the bronze bosh plate, is more than offset by greater first cost, liability of leaks, and difficulty of locating same.

It seems on the face of it that there should be no danger of any water leaking into the interior of the furnace with a system of external cooling, such as the steel bosh jacket, but this, however, has not, as a rule, been the case. The construction is responsible for this defect, for it is the universal practice to form the lower part of the jacket into a trough in which the cooling water is collected; and as the inside lower corner of this trough is subjected to severe strains, due to varying temperatures of the inner wall, the joints soon begin to leak, and the water may even flow into the furnace when the blast is on, but usually only when the blast is off.

This, however, inasmuch as it is irregular, may amount, in a short shut-down, to a severe chilling of the hearth. In order to obviate this trouble, the writer designed a jacket where the water collecting trough is outside of the furnace; this not only prevents water leaking into the furnace, but increases the life of the jacket, for the entire surface is thus kept clean, whereas, where the trough is built at the foot of the jacket, dirt will accumulate in it, thus keeping the water away from the plate and very materially shortening the life of the jacket.

Fig. 2.


21
20
2
15
10
9
12
16
21
13
9
6
14
2
16
20
3
2x
15
11
9
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16
15
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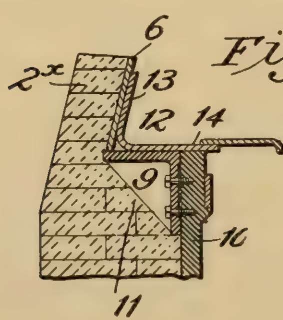
6
2x
13
12
14
9
10
11

Fig. 3.

In the accompanying drawings, Fig. 1 is an elevation, partly in section, of the lower part of a blast furnace having my invention embodied therein. Fig. 2 is a sectional plan view looking downward, portions being broken away to expose their parts to view. Fig. 3 is a vertical section, on an enlarged scale, showing the supporting-brackets at the base of the bosh wall for sustaining the cooling jacket.

Referring to the drawings, 1 represents the body of the furnace, supported by the usual columns 2, arranged at intervals around the same.

2x represents the bosh wall of the furnace, and 3 the hearth, inclosed by wall 4, which at its junction with the bosh wall extends outward, forming a ledge 5.

6 represents a cooling jacket comprising a metallic sheath or casing which closely surrounds the bosh wall, and which is encircled by a number of distributing gutters 7, fixed thereto one above the other and formed at their bases so that water supplied to the upper gutter from supply pipe 8 will be received by the several gutters and be by them distributed in a film over the intervening surface of the jacket.

At its lower end the jacket rests on, and is supported by, the inner ends of a series of brackets 9, fixed to the inner face of a heavy band or ring 10, encircling the upper portion of the wall 4, which band is supported at its lower end by a projecting portion 11 of said wall, the said brackets being embedded or built in the wall. As a result of this arrangement the bosh wall is free from the weight of the jacket, which latter is given firm support from beneath and is effectually retained in position.

In the angle formed where the bottom of the jacket meets the ledge 5 is fixed an angular annular plate 12, comprising an upright portion 13, closely surrounding the lower end of the jacket, and a horizontal, outwardly-projecting portion 14, which rests on the ledge 5 and extends outward beyond the same and has its edge turned downwardly and forming a discharge plate, so that the water as it passes over the jacket is received by this annular plate and is permitted to pass freely over the same, and flowing over the discharge plate, it is directed into, and enters, a receiving trough 15, surrounding the wall 4 some distance from it and arranged vertically beneath the edge of the discharge plate.

The trough 15 may be sustained in any suitable manner, provided that it is free of the furnace wall and receives no support therefrom; but I prefer to support the trough on the inner ends of a series of brackets 16, fixed at their outer sides to the inner faces ot the supporting columns 2, as clearly shown in Fig. 1. By thus sustaining the trough free of the furnace wall and allowing the water passing over the jacket to flow freely from the base of the same into the trough there will be no accumulation of water at the base of the bosh wall, and no danger, therefore, of leakage into the furnace in the event of the wall cracking or parting. Furthermore, the trough, being outside and free of the wall, will not be subjected to strains from the expansion or contraction of the walls or jackets, such as would cause the seams of the trough to open.

The water may be discharged from the receiving trough in any suitable manner, and I have shown for this purpose a series of drain pipes 20, leading from the bottom of the trough and discharging into spouts 21.

It will be observed from the construction shown and described that the annular plate at the bottom of the jacket forms a horizontal uninterrupted continuation of the outer surface of the jacket, so that the water flowing over the exterior of the jacket is not retarded or interrupted, but passes freely and uniformly on to the plate and in like manner over the same and is finally discharged over its edge.

I believe that no one type of bosh cooling is applicable to all blast furnaces, but that each system has its advantages and, under certain conditions, one is better than the other.

It is also of great advantage, under some conditions, to combine both systems, and some of the modern large stacks are so equipped. Wherever the steel jacket is used, however, the improvement just described will be found a simple and effective device to materially increase its efficiency without increasing the cost.

THE CONSTITUTION OF IRON-CARBON ALLOYS*

STABLE AND METASTABLE EQUILIBRIA IN IRON-CARBON ALLOYS

By E. HEYN, Charlottenburg

Translated for The Iron and Steel Magazine by MILES S. SHERRILL, Massachusetts Institute of Technology

IN connection with the address† by Prof. Bakhuis Roozeboom I should like to present my views regarding the phenomena occurring on the quenching and on the solidification of iron-carbon alloys. They are founded, for the most part, on evidence obtained from microscopic observations. The investigation of the nature of alloys under the different conditions determined by the practical use to which they are put forms the goal of the science of metallography, a branch of applied physical chemistry. This science has advanced enormously with the building up of the theory of solutions and the development of the phase doctrine, especially with the investigations of Professor Roozeboom. The important rôle which the microscope has played in its development, and the problems which in the future await solution by means of microscopic investigation, should, however, not be forgotten. It should always be borne in mind that the phase doctrine furnishes us information regarding stable equilibria only. The microscope, on the other hand, is almost the only expedient which enlightens us as to how well these stable conditions of equilibria are realized, and how we are to consider the intermediate unstable or metastable conditions in which many alloys (on account of the especial properties characteristic of these conditions) find practical application. I should also like to take this opportunity to observe that the credit of having introduced the microscope into the service of the science of metallography is due to Prof. A. Martens, the director of the Royal Bureau for Testing Materials, at Gross-Lichterfelde, near Berlin (formerly mechanical-technical experiment station in Charlottenburg). I shall assume that the part which this bureau has taken in the development of this science is known, and only call attention to the fact that, since the begin-

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* "Zeitsch. f. Elektro-Chemie," Vol. X (1904), 491.
† *Ibid.*, 489.

ning of its activity it has always been a place for fostering this important branch of physical chemistry.

A. The Phenomena Occurring on Quenching Iron-Carbon Alloys

The relations which are established when iron-carbon alloys are cooled so slowly from temperatures above 700° that stable equilibrium is obtained must here be touched upon very briefly. I assume in the beginning that the fundaments are known. The main features have been given by Osmond, Roberts-Austen and others, and have just been explained, somewhat more in detail, by Professor Roozeboom.*

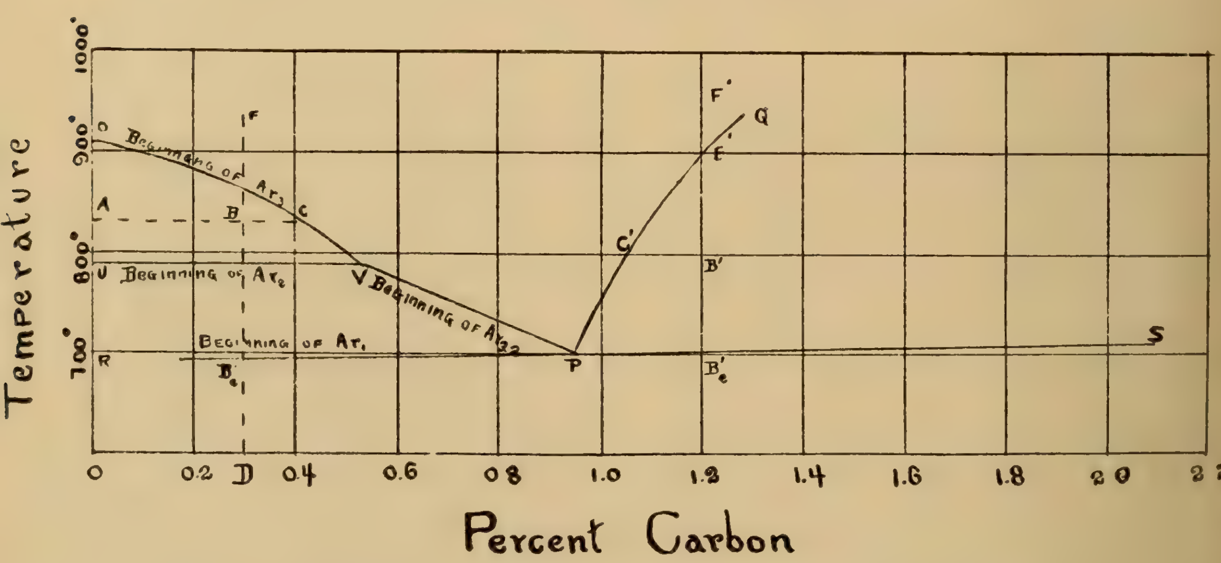

Fig. 1. Diagram of Critical Points on Cooling Iron-Carbon Alloys.

All of the changes which take place below 910°, and therefore in the solid state, are illustrated by the diagram in Fig. 1. This diagram is based on observations made by the author. Except for a few deviations, it agrees with that of Roberts-Austen.

The point O corresponds to the allotropic change of γ- to β-iron. With this, as well as with the transition from one

* The changes are explained in a more popular manner in a little pamphlet by E. Heyn, entitled "Die Metallographie im Dienste der Hüttenkunde," and published by Craz and Gerlach, Freiberg in Sachsen, 1903.

state of aggregation to another, there is connected a change of the solubility relationships. Gamma-iron is capable of holding a certain definite amount of carbon in solid solution; β-iron does not possess this power. The line PQ would, if extended, lead to the second component of the system, iron-carbide, Fe_3C. P corresponds to the eutectic point. At U the iron undergoes a second allotropic change. Beta-iron changes over into α-iron, which is likewise incapable of holding any carbon in solid solution. The line UV, which represents these transitions, has no real influence on the structure as revealed under the microscope, and may, therefore, for simplicity, be left out of consideration.

FIG. 2. Wrought Iron. 0.05% C. Magnified 90 diam.

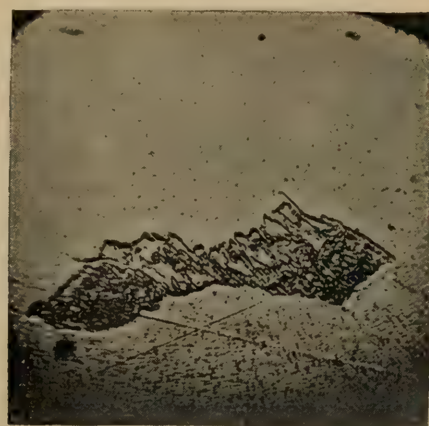

FIG. 3. Wrought Iron, same as Fig. 2. Magnified 680 diam.

It does, however, have a marked influence on the magnetic properties.

With cooling sufficiently slow to permit the attainment of stable equilibrium, it follows from the diagram and the phase doctrine that below the eutectic line RPS (700°) cnly the two phases iron and iron-carbide (Fe_3C), known as ferrite and cementite respectively, should take part in forming the internal structure of the alloy. This can be verified by means of the microscope. In addition to this there is to be noted a special arrangement of the two phases. The solid mother liquor, containing 0.95 per cent carbon (corresponding to the point P), which remains in all alloys at 700°, decomposes into an intimate mixture of ferrite and cementite. The latter has such a characteristic appearance that it is designated as a special

constituent called pearlite. The constitution to be expected is, therefore, as follows:

Iron with less than 0.95 per cent carbon: ferrite and pearlite. With increasing carbon content from 0 to 0.95 per cent, the percentage area occupied by the pearlite in the field increases from 0 to 100 per cent.

Iron with 0.95 per cent carbon: pearlite only.

Iron with more than 0.95 per cent carbon: pearlite and cementite.

As proof of this the photomicrographs, Figs. 2 to 8, should be examined. The first photograph shows the structure of a wrought iron with 0.05 per cent carbon. The main part of the field consists of the bright ferrite. Imbedded in this lie dark

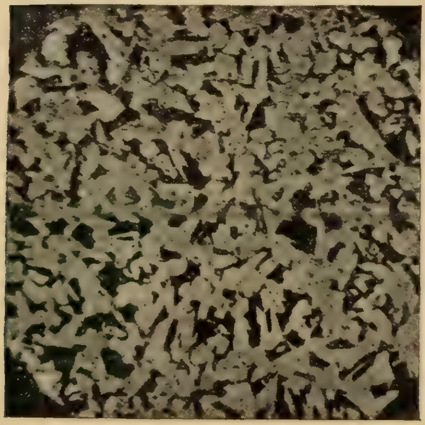

Fig. 4. Medium Hard Steel. 0.30% C. Magnified 90 diam.

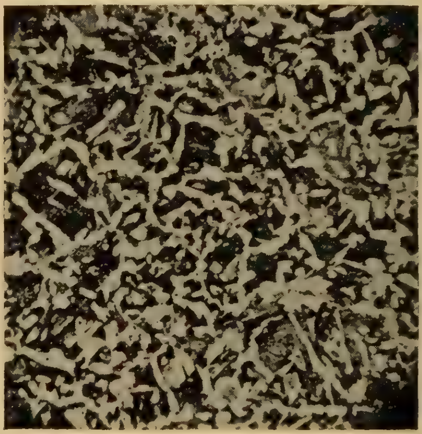

Fig. 5. Medium Hard Steel. 0.41% C. Magnified 90 diam.

little islands of pearlite. The characteristics of the latter become visible only under higher magnification. One of these little islands is shown in Fig. 3. It shows distinctly a structure built up of alternate lamellæ of ferrite and cementite, as is the rule with eutectic mixtures. Photograph 4 shows the structure of an ingot iron with 0.30 per cent carbon. The light constituent is ferrite; the dark, pearlite. The latter would, if more highly magnified, show a structure similar to that pictured in photograph 2. The pearlite here requires about 30 per cent of the whole field of view. When the carbon content of the alloy reaches about 0.5 per cent, the structure becomes that shown in photograph 5. The bright

particles are ferrite, the darker ones pearlite. Each occupies about 50 per cent of the field of view. Figure 6 shows very distinctly the characteristic details of the pearlite in a similar alloy. In photograph 7 is depicted the structure of an alloy containing 0.95 per cent carbon. As was to be expected from the above considerations, there is only one constituent present, namely, pearlite. If the carbon content be increased still more, to 2.16 per cent for example, there appears, in addition to the pearlite,

FIG. 6. Medium Hard Steel. 0.45% C. Magnified 1,000 diam. (Osmond).

a new constituent of great hardness, cementite. This is shown in photograph 8. The white veins are cementite; the remainder is distinctly the characteristic pearlite.

Figure 9, in which the percentage area of the field of view occupied by the pearlite is plotted as a function of the carbon content, shows how the quantity of pearlite increases with an increasing carbon content.

I should like to point out here that, although with sufficiently slow cooling all of the above constituents occur pure, with somewhat accelerated cooling, the pearlite consists no longer of the two uncolored constituents, ferrite and cementite. Under conditions exactly the same, except for the somewhat more rapid cooling, one or even both of the constituents forming the

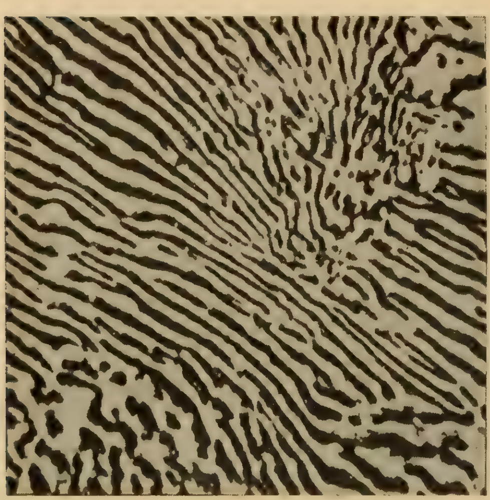

FIG. 7. Steel 0.95% C. Magnified 1,000 diam. (Osmond).

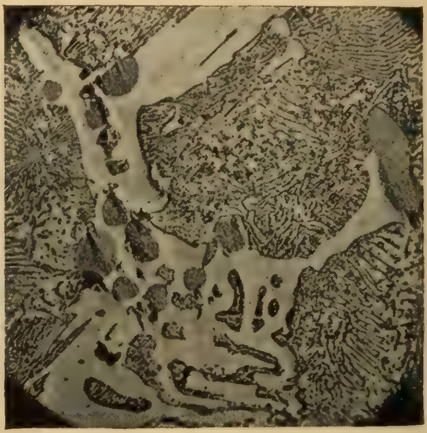

FIG. 8. Iron Containing 2.16% C. Magnified 270 diam.

pearlite become colored. In other words, the final products, iron and iron carbide, are not reached because of insufficient time. Photographs 10 and 11 represent the pearlite of the same white cast iron. Photograph 11 shows the pearlite in the cast material (2.49 per cent carbon). As a result of the rapid cooling, the pearlite has not separated completely into its components. One of the two constituents is colored. Photograph 10 shows the pearlite in the same iron after annealing at red heat, whereby the carbon content fell to 2.16 per cent, and very slow cooling. In this case complete decomposition of the pearlite into the final products has occurred.

Naturally, here, only that time is to be taken into consideration which is allowed for the cooling from the points on the curve OVPQ to just below the eutectic line RPS; that is, only the rate of cooling within the temperature range in which the reactions represented in the diagram (Fig. 1) take place. If stable equilibrium has once been reached, and the temperature, therefore,

fallen below 700°, the velocity of subsequent cooling has no effect on the constitution.

The rate at which the temperatures above 700° are

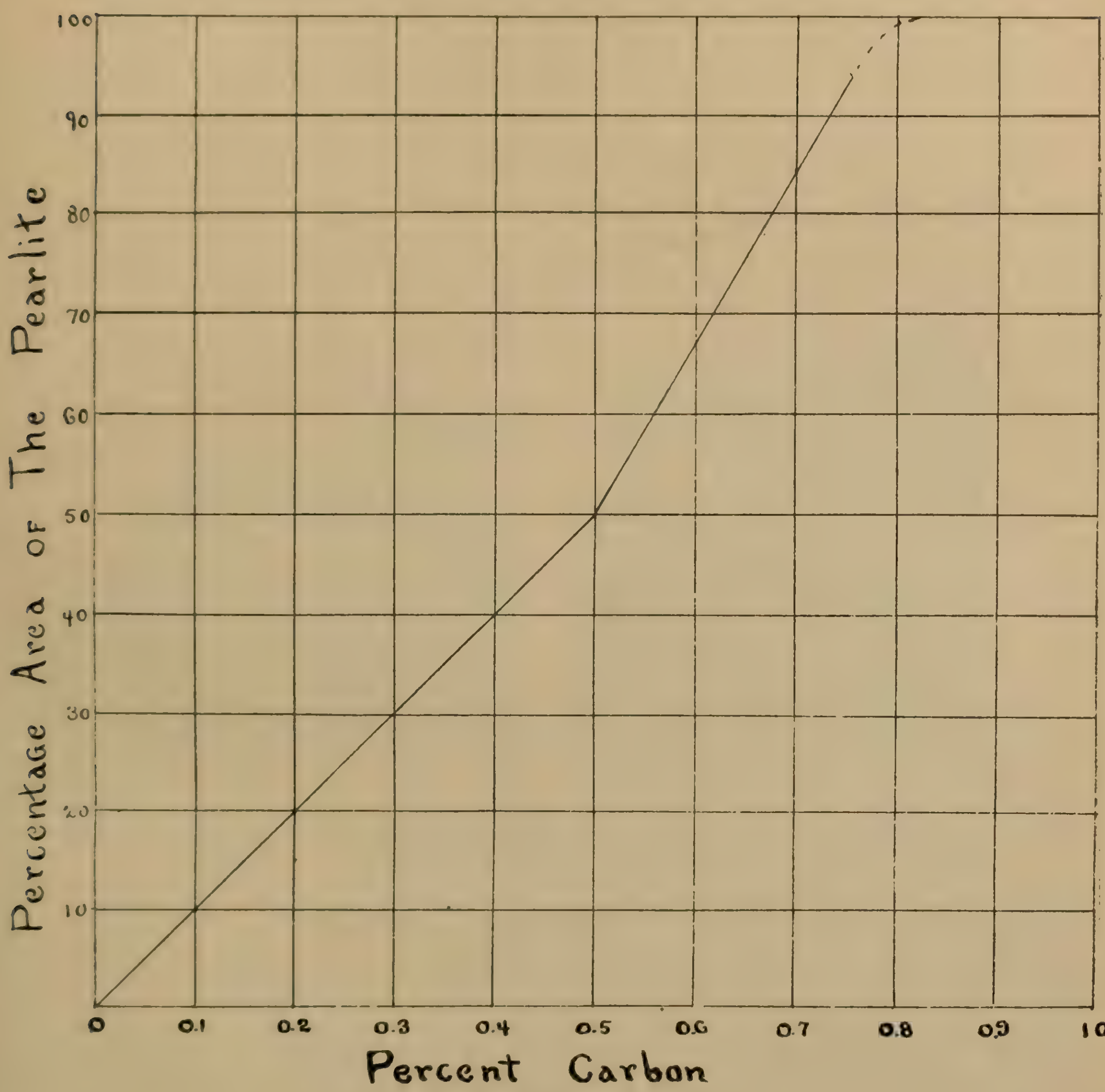

FIG. 9

passed over by the alloy on cooling from a higher temperature is, however, of the greatest importance, especially for the heat treatment of steels. The state of affairs would be extremely simple if the assumption were correct that by sudden quenching from a definite temperature T, above 700° (quenching

temperature), the condition corresponding to stable equilibrium within the material at T be held at lower temperatures t (for example, room temperature). Of course the system would exist here in an unstable condition of equilibrium not corresponding to the temperature t. This would be synonymous with a complete, perfect "supercooling." Such a case, for example, occurs in the glasses. They should, at the temperatures at which we use them, have long decomposed into a mixture of crystals of one or more components, that is, have devitrified. The devitrified condition would correspond to the stable equilibrium, which is sometimes suddenly established, though unintentionally, in many glasses. In the condition in which it is ordinarily used,

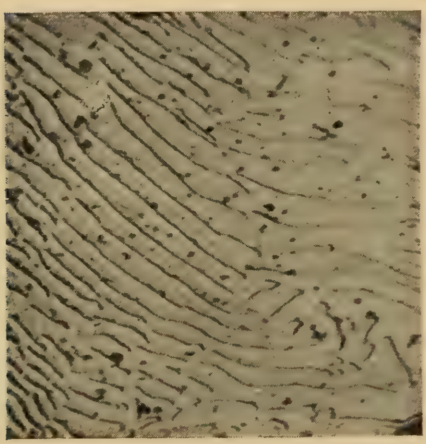

FIG. 10. Pig Iron 2.49% C. Annealed. Magnified 1,240 diam.

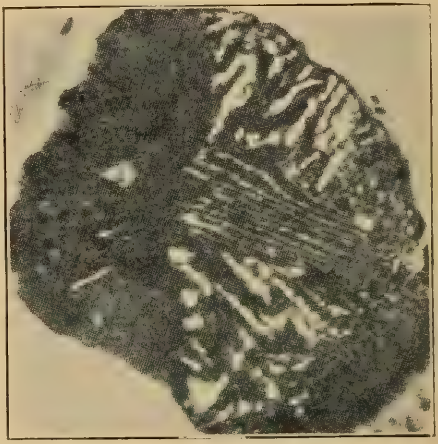

FIG. 11. Pig Iron. Same as Fig. 10 as cast. Magnified 1,240 diam.

however, glass represents a good example of perfect supercooling. The individual substances, dissolved in each other, retain the complete solubility which is characteristic of them in the molten state at much lower temperatures, though of course the condition is one of unstable equilibrium. The unstable condition changes over to the stable or devitrified condition with considerable difficulty. In fact, the utility of glass for our purposes is due to this circumstance. The tendency toward supercooling varies with different substances. With silicates and borates it is very marked. Often on account of internal tension, the supercooled and therefore unstable condition is more brittle than that corresponding to stable equilibrium. The

latter statement is true of quenched iron-carbon alloys, which exist in unstable equilibrium.

If, in the case of iron-carbon alloys, complete supercooling (as defined above), as result of quenching, be assumed as a working hypothesis, then, for example, an alloy D with 0.3 per cent carbon (see Fig. 1) would give, according to the temperature chosen for quenching the following relations:

(*a*) Let the quenching temperature lie above E, say at F. The point F lies above OVPQ and therefore in the region where the mixed crystals of γ-iron and carbide represent stable equilibrium. These mixed crystals will, for brevity, be designated by M. They contain in the chosen case 0.3 per cent carbon, which will be indicated by the symbol M0.3. At the temperature F, they must be homogeneous. They may, nevertheless, be subdivided into single crystalline units, somewhat as marble consists of nothing but homogeneous crystals of calcite. According to the assumption, this condition, upon suddenly quenching at F in water, would remain unchanged; that is, complete supercooling would occur. The structure would be composed of only one constituent, M0.3.

(*b*) Let the quenching temperature be assumed to lie between E and Be, for example, at B. Let the cooling from higher temperatures to B take place so slowly that at B stable equilibrium is reached. It must then, according to the phase doctrine, consist of:

Separated iron (ferrite) crystals (corresponding to the point A), containing 0 per cent carbon and mixed crystals M (corresponding to the point C), containing 0.4 per cent carbon, M0.40.

The relative amounts of each is given by the ratio,

$$\frac{\text{ferrite crystals}}{\text{M}0.40} = \frac{\text{BC}}{\text{AB}} = \text{approximately } \frac{1}{3}.$$

Therefore, neglecting the slight differences in specific gravity, there would be present in the field of view,

$$\text{Ferrite} = 25\%,$$
$$\text{M}0.40 = 75\%.$$

On slowly cooling from B to 700°, the quality of the ferrite crystals would remain unchanged, their quantity, on the other hand, would increase. The quantity of M would decrease and its

carbon content increase, till, at 700°, the relative amounts present would have become

$$\frac{\text{ferrite crystals}}{\text{Mo.95}} = \frac{\text{BeP}}{\text{RBe}} = \text{approximately } \frac{13}{4},$$

corresponding to a surface division of

$$\text{Ferrite} = 77\%,$$
$$\text{Mo.95} = 23\%.$$

The carbon content of M would have reached its maximum value, namely, the composition of the eutectic with 0.95 per cent carbon. By slowly cooling through 700° the relative amounts present would remain unchanged; only Mo.95 would decompose into an intimate mixture of the two phases, ferrite and cementite, which is known as pearlite.

As soon as the cooling from B took place rapidly enough (quenching), it would, always bearing in mind the original assumption, be expected that the condition of stable equilibrium at B (ferrite + Mo.40 in the ratio of 25 to 75 per cent) would be retained in unstable equilibrium at the lower temperature *t*.

Since, according to the position of the quenching temperature B, between the boundaries E and Be, the ratio $\frac{BC}{AB}$ varies between the limits 0 and $\frac{13}{4}$, and therefore from the above considerations, the quantity of ferrite from 0 to 77 per cent, it would be possible to draw conclusions from the structure of the quenched (supercooled) steel as to the temperature B, at which it had been quenched. This is, in fact, practically possible.

If an alloy containing more than 0.95 per cent carbon were chosen, analogous relations would be obtained. So, with an alloy containing 1.2 per cent carbon, for example, there would be expected,

(*a*) Quenching temperature T, above E′, say at F′. Only mixed crystals M1.2 with 1.2 per cent carbon.

(*b*) Quenching temperature T between E′ and Be′, say at B′. Cementite crystals A′,* and mixed crystals C′, M1.04 with about 1.04 per cent carbon, in the ratio

* A′ is not shown in Fig. 1. This point would be on an ordinate passing through the abscissa 6.67 per cent, corresponding to the percentage composition of the carbide.

$$\frac{\text{Cementite}}{M_{1.04}} = \frac{C'B'}{B'A'}.$$

The alloy with 0.95 per cent carbon (the eutectic alloy) occupies an exceptional position. The range EB_e, or $E'B_e'$, is here reduced to zero. Therefore, if quenched at any temperature above 700°, it must contain mixed crystals $M_{0.95}$ only, unmixed with free ferrite or cementite.

It is clear from the preceding discussion that the mixed crystals M may contain different amounts of carbon. Their percentage content of carbon, above indicated by means of the index, depends on the temperature at which quenched and the carbon content of the steel which has been quenched.

Evidence obtained from microscopic observation indicates, however, that the assumption made above of the possibility of attaining complete supercooling in the case of iron-carbon alloys is not valid. Supercooling phenomena do occur, but they do not attain the same degree of perfection as with glass. That is to say, the unstable equilibrium resulting from the quenching of the alloy no longer corresponds exactly to the condition stable at the quenching temperature, but, according to the severity of the quenching and the conditions under which it is carried out, there is retained an unstable condition which lies between the stable condition corresponding to the quenching temperature and that corresponding to stable equilibrium at ordinary temperatures. According to circumstances, it may sometimes approach more nearly the former and sometimes the latter. There must exist, therefore, transition constituents between the mixed crystals, retained pure and unchanged even at ordinary temperatures, but representing unstable equilibrium, and the pearlite the form stable at these temperatures. Since the phase doctrine is only valid for stable equilibrium relations, these transition constituents must not be considered as phases.

(*To be continued*)

FUNDAMENTAL PRINCIPLES INVOLVED IN BLAST-FURNACE PRACTICE *

By EDWARD A. UEHLING, M.E.

TO produce with the greatest possible regularity and fuel economy the maximum per cent of the quality of iron desired, and the maximum output of which the design of the furnace and its mechanical equipment will permit, none of the recognized essentials must be overlooked, and many things observed and attended to that have not received the consideration which their importance merits.

Raw Material

The ore should be of uniform quality, or a uniform mixture of ores of dissimilar qualities, chemically adapted to yield collectively the iron desired, and to produce with the flux available that quantity and composition of slag best adapted to fulfill its proper functions in the process of smelting. Neither a very lean ore, or ore mixture, nor yet ores that are exceedingly rich in iron, are conducive to obtaining the best results, but a regular mixture of low-grade ores will yield better results than an irregular mixture of much higher average grade, certainly as to quality and generally also as to quantity of output. In regard to a few of the chemical elements, the ore must be, and always is, selected and mixed to produce the desired iron; but in regard to the physical condition there is at best but a limited choice, and frequently none whatever. It may be laid down as an axiom that the more refractory an ore is the finer it should be physically to become readily reduced. In the storeroom of nature we find, however, that the more refractory ores occur generally in compact masses, while those easily reducible are most frequently found in a more or less finely comminuted state.

The logical corollary to the above axiom, viz., that the finer the comminution of an ore the greater its reducibility, and hence the more readily it can be smelted, while theoretically correct, does not hold good in the blast furnace, and especially not in the modern blast furnace. Two reasons why this should be so present themselves very readily; first, the finer the ore the

* "The Journal of the Franklin Institute," February, 1905.

greater must be the resistance offered to the ascending gases, and, second, the greater must also be the quantity of ore dust carried over into the gas flues. These difficulties give rise to others which with certain ores have frequently proven serious.

In smelting very fine ores the increased blast pressure was the objection that made itself felt first, and in the measure as this was being overcome by stronger blowing engines, the loss in flue dust was increased. No serious difficulties were encountered, however, until after the advent of the ores from the Mesabi range. These ores, while unsurpassed in chemical composition, ease of reduction and cheapness of getting, possess physical properties which illy adapt them for conversion into pig iron in the monstrous blast furnaces in which they are being smelted. In the majority of the deposits the very fine ore preponderates, in some cases as high as 20 per cent will pass through an 80-mesh sieve. Much of this very fine ore is carried over with the gases. The average loss of Mesabi ore in flue dust is between 3 and 5 per cent, and greater loss is not uncommon.

Preparation of Ores

Crushing. — Although much advance has been made in the past decade in the way of preparing the harder varieties of ore by crushing them, generally at the mines, which is the proper place, instead of depending on a few men in the stock-house to break up the largest lumps with sledge hammers, yet little or no attention has been given to the actual requirements. All hard ores are crushed to a given size, irrespective of their reducibility. Hematite ores generally go into the furnace in a finer state of comminution than magnetites, when, because of their great reducibility, the reverse should be the case. It is the author's opinion that all hard ores could bear much finer crushing than is at present customary, and that this would be conducive to fuel economy particularly with the magnetites. The latter could be crushed with advantage so as to pass through a 2-inch round-holed screen, and even smaller.

Sizing. — The importance of sizing or separating ores with regard to their relative coarseness or fineness has as yet received but little attention in American blast-furnace practice. I dare say the majority of furnace managers have not given this phase of the subject the thought and careful study it deserves.

Every furnace man objects to either very fine or very coarse ores, and all would, no doubt, prefer a uniform and relatively coarse ore; but since it is quite the exception that uniformly coarse ores can be supplied, they must be taken as they come, and the general practice is to charge the coarse and fine ores indiscriminately as they happen to be at hand, or, at best, attempt to mix them as much as possible. The former method is bound to produce more or less serious disturbance in the working of the furnace; not only because of the physical irregularity, but also because the fines of a given ore may vary very considerably in composition from the coarser portions. The uniform mixing of the coarse and fine ores, though much better chemically at least, is, nevertheless, far from being the best method of charging.

The worst possible ore mixture, from a physical point of view, is that in which the coarse and fine are so proportioned and so thoroughly mixed that the latter fills all the interstices between the lumps of the former. A layer of such a mixture is less penetrable, offers greater resistance to the ascending gases, hence requires a higher blast pressure and is apt to produce more flue dust, and is, therefore, less desirable than if it consisted of fine ore alone. This is true to a greater or lesser extent of all mixtures of irregular sizes, and the greater the difference between the coarse and the fine, the worse. To be right, ores should be separated into three, or preferably into four, sizes, viz., coarse, medium, fine and dust. All ore passing over, say, $1\frac{1}{2}$-inch mesh screen to be classed as coarse; through $1\frac{1}{2}$-inch and over $\frac{1}{2}$-inch to be classed as medium; through $\frac{1}{2}$-inch and over $\frac{1}{20}$-inch mesh to be classed as fine, and all that passes through $\frac{1}{20}$-inch mesh to be classed as dust. The latter should either be briquetted or agglutinated in some satisfactory manner, or else smelted in a furnace by itself, designed and equipped for the purpose, preferably in a low, wide furnace, blown with a mild blast through tuyères of variable penetration, or, perhaps, electrically. The coarse, medium and fine ores could be smelted together in the same furnace with a strong blast. To do so to the best advantage they should be charged in separate strata. The above scheme, *i. e.*, to first separate the ore into several sizes and then fill them separately, will, no doubt, be objected to as impracticable, as an expensive and useless complication, or, at

best, a refinement of doubtful utility. Whether such objections are all, or only partly, or not at all true, depends on our viewpoint. If we should attempt it with the present equipments, even the most modern, it would probably be impracticable; if we feel that we have reached the acme of perfection in blast-furnace practice, it must seem a useless complication, and if the present output is qualitatively as well as quantitatively fully satisfactory, the sizing of the ores would certainly be of doubtful utility. If, however, we wish to combine uniform quality with maximum output and greatest fuel economy, we must seek to eliminate all disturbing factors, and the physical irregularity of the raw material certainly is one of them.

Roasting the ores is resorted to generally only for the purpose of eliminating such deleterious constituents from the ore as can be driven off by heat. The process is always carried on in an oxidizing atmosphere. In this country the roasting of ores is rarely resorted to, except for the purpose of eliminating sulphur. All magnetic ores are improved by roasting, and the question whether it would pay or not to do so depends entirely on local conditions; first, on the cost of coke or other furnace fuel, and second, on the market value of electric current. The same is true with other varieties of ores; for example, the hard red ores of the Birmingham district, which could be greatly improved by roasting. Time and space do not permit going further into this subject at this time.

Briquetting, Agglutinizing, Cindering, Electric and Chemical Treatment. — All these relate to putting ore dust into some form that will overcome its objectionable qualities. Much time, ingenuity and money have been expended in this direction, resulting mostly in failure, or at best in indifferent success. This, however, does not imply that the problem cannot be solved, or even that it may not have been solved already by some method awaiting practical demonstration and commercial development. Much could be said about promising methods, if time permitted.

As stated above, theoretically, the finer the ore, the more economically it should be smelted. To the practical objections already mentioned which manifest themselves against the use of very fine ores, viz., heavy blast pressures and reduced yield, etc., should be added the difficulty encountered in properly

distributing the fine ores over the coke charge. The latter problem fully solved, the author is of the opinion that the very fine ores could be smelted to best advantage by themselves in a specially designed blast furnace. Smelting in an electrical furnace possesses possibilities of success which depend chiefly on the cost of power, and with the proper utilization of the blast-furnace gas its practicability as an adjunct to the blast furnace becomes very much less doubtful, and may prove profitable under certain local conditions.

Flux. — Under the general term of flux, we understand that addition to the material smelted which will chemically combine with the gangue and other impurities of both ore and fuel and produce a liquid slag. It so happens that with very few exceptions the acid elements contained in the gangue largely predominate. For this reason, the flux must nearly always be basic; and because of its abundance and cheapness, limestone is almost invariably used. Should, however, the basic element in the ores predominate, an acid flux would have to be added, and quartz rock or highly siliceous iron ore takes the place of limestone.

Preparation of Flux. — What has been said of the preparations of ores holds good in a general way also for the preparation of the flux. It should be well broken, and as much as possible of uniform size; dust should be entirely avoided. Theoretically, it would be of considerable advantage to calcine the limestone or dolomite before filling into the furnace. There are, however, practical difficulties due to the fact that unless the stone is very hard burned, it readily becomes air-slaked, and is then worthless, since it is too largely carried over by the blast. Attempts that have been made to drive off the carbonic acid before filling into the furnace have generally failed on that account.

Slag. — The function of the flux, as we have seen, is to fuse with earthly impurities of the ores and fuel and melt into a liquid slag. The function of the slag is twofold, — physical and chemical. Physically it acts first as a filter, purifying the globules of reduced iron as they pass through, and, second, as a blanket, protecting the metal against possible oxidation by the blast. Chemically its most important functions are to absorb and carry off sulphur, and to assist in regulating the silicon content in the iron.

Magnesia is a stronger flux than lime in ratio of their respec-

tive atomic weights, and with an ore mixture comparatively free from sulphur smelted with a low sulphur fuel, dolomite is proportionately more efficient than carbonate of lime; but since sulphur exists in the slag only in combination with calcium, the latter element must predominate where considerable quantities of sulphur are to be removed.

The proper composition of the slag is of greatest importance, and, in selecting ores, and also the fuel, due consideration should be given to the composition of the gangue and ash respectively. Alumina should be kept as low as possible. Although this element does not materially reduce the fusibility, it does largely reduce the fluidity of the slag, and fluidity is of the most vital importance in a blast-furnace slag. So far as the author's experience goes, the lower the alumina can be kept the better; and if a slag results from the regular mixture containing over 15 per cent of alumina, silicon material should be added to the burden. A slag to be most efficient should melt like ice, and not like taffy; that is to say, it should retain a solid form until it melts, and as soon as melted it should be quite liquid, instead of gradually passing from the solid to the liquid state. The latter property causes sticking and hanging, and on account of the sluggishness of such a slag, it cannot fulfill its functions properly. It has a tendency to retain the finer globules of iron, thus causing material loss.

Generally the ores contain ample earthy impurities so that with the addition of flux necessary to form a desirable slag the proper quantity is also produced. In many instances it has proved to be good practice to add siliceous material for the purpose of improving the quality of the slag as well as of increasing the quantity.

Fuel. — The fuel for the blast furnace may be raw coal, charcoal, anthracite or coke. The first of these has entirely ceased to be a factor in the production of pig iron in this country. The percentage of charcoal used is becoming less and less as timber becomes scarcer and dearer. The same holds true for anthracite coal, because of its limited supply, and although still used in considerable quantities it is bound to be practically replaced by coke in the not distant future. Coke, besides its practically unlimited supply, possesses all the essential qualities of a superior blast-furnace fuel.

The fuel performs two functions in the blast furnace, — physical and chemical. The physical function of the fuel consists in preserving a comparatively open stratification in the descending column of stock in the furnace, thereby permitting an easy upward flow of the ascending gases. To fulfill this function properly the fuel should be coarse and rough, and as uniform as possible in size. Very large lumps are as undesirable as fines. It should be of sufficient strength to reach the tuyères with the least loss by abrasion. Fuel dust, or breeze, should never be charged into a blast furnace; the most of it is directly blown over with the gas, and what little is retained in the furnace is apt to do more harm than good.

The chemical functions of a blast-furnace fuel are two-fold: (1) To generate by semi-combustion with the oxygen of the blast all the heat necessary for the process of smelting, and (2) to produce the reducing gas necessary to convert the ore to the metallic state. It should possess the greatest possible cell development consistent with the required physical strength, so as to offer the maximum surface to the oxygen of the blast, and yet possess such chemical stability that it is but slightly affected by the oxidizing action of the CO_2 in the upper zones of the furnace. To possess these properties the first requisite is that the coke is well burned and made from coal which will produce the proper cell structure and necessary strength.

The most objectionable element contained in coke is sulphur. Phosphorus is of importance only when special irons are being manufactured. The composition of the ash is of as much importance as the quantity. The alumina should be as low and the silicon as high as possible. This holds true especially where foundry iron is smelted. Iron is a valuable constituent, and is often contained in sufficient quantity to add appreciably to the yield of the ore. The author is of the belief that most of the silicon in the iron produced comes from the ash of the coke; and if the ash, therefore, is of the proper composition it may add materially to the ease of producing high silicon iron.

Air. — The largest, the cheapest, and the most neglected constituent of the raw materials involved in the process of smelting is the air which furnishes the oxygen required to burn the fuel and produce the heat and chemical reactions.

Strictly speaking, the blast is furnished to every furnace

variable in quantity, irregular in temperature and, worst of all, variably contaminated by moisture, and, because of these, as much as other irregularities, also at variable pressures.

Regularity of Blast. — First, regular quantity. It is probably quite within the memory of most of the older furnace men, if not within their own experience, that it was the general practice to regulate the blast by pressure. In England, where they still generally blow several furnaces (as many as six or more) off the same blast main, this practice of necessity prevails. In this country blowing by volume is the rule. The blowing engines are ordered to be run steadily at the required revolutions; but variable steam pressure is a disturbing factor, variable blast pressure is another. Then again constant revolutions, *i. e.*, constant volume by engine measurement does not insure a constant quantity of blast delivered into the furnace. Innumerable avoidable and unavoidable leaks, between piston and tuyères, engine-room temperature and the barometric pressure of the atmosphere, affect the quantity delivered. The latter alone may affect the quantity delivered from 6 to 10 per cent, and loss through leakage from 10 to 15 per cent and more is not uncommon.

The author believes himself to have been among the first to blow a furnace by constant volume. The change from pressure to volume blowing at once brought a noticeable improvement in the regularity of the output, but the number of charges taken by the furnace did not agree as closely as they should with the regular quantity of wind supposed to be delivered by the blowing engines. Revolution counters were attached to the engines, and the fact was at once revealed that the revolutions marked had not been regularly blown. Getting the engineers interested resulted in a friendly rivalry to blow the exact number of revolutions. For longer or shorter intervals the fuel charges would agree with the revolutions, then again there would be puzzling discrepancies that could not be explained by irregularities in the working of the furnace. Barometer and thermometer observations finally practically cleared away all otherwise unaccountable discrepancies, except that the calculation showed the quantity of air delivered by the blowing engine to be far in excess of that required to burn the fuel consumed. The numerous small leaks, which had not been considered of much importance prior

to accurate determination of wind and fuel relation, were stopped and a gain of 5 tons per day was the result.

These few digressive remarks are recited here merely to show the importance of small things. There is so much in the phenomena of smelting in a blast furnace which cannot be directly observed that it behooves every furnace manager who wishes to keep intelligent control over his charge to pay attention to all the influencing factors. The barometer and the wet and dry bulb thermometer have received practically no attention. Revolution counters are not as generally adopted as they should be. Autographic recording instruments should be used wherever available. The fact that the cost of air does not directly enter into the cost sheet is no reason why it should not receive proper attention.

Regular Temperature. — Neilson's invention of the hot-blast stove was, no doubt, the greatest single step taken in advance in the process of smelting iron in the blast furnace. Every 100 degrees of heat added to the temperature of the blast is equivalent to 3 per cent of the carbon burned at the tuyères.

To what degree it is practical and economical to carry the heat of the blast is still an undetermined question. Practical furnace men differ much in their opinion. Sir Lowthian Bell came to the conclusion, derived from his famous investigation of the chemical phenomena of the blast furnace, that not much could be gained after reaching 1000°; nevertheless they are to-day carrying at his own furnaces as regularly as possible from 1400° to 1500° at the Clarence Works, Middlesbrough, England. In Germany 1500° to 1600° of blast temperature are not uncommon. In this country the average blast temperature does probably not very much exceed 1000°. Some furnace managers would like to carry higher temperatures if they could get them; others contend that high blast temperatures invariably lead to trouble. Theoretically, the limit of blast temperature is not reached until the fuel displaced by the heat of the blast has reduced the quantity to such an extent that the CO formed is insufficient in quantity to reduce the ores carried. The blast furnace cannot be successfully worked on heat alone. A sufficient quantity of reducing agent must be supplied as well, and there must be enough solid fuel to fulfill its physical function. While there is, therefore, ample room for difference of opinion

as to what is the most economical temperature, there exists no such difference of opinion as to the desirability of a controllable regular temperature.

The introduction of the regenerative hot-blast stove was a great improvement over the iron-pipe stove in so far as enabling higher temperatures to be obtained; at the same time, it brought with it the very detrimental factor of variability of temperature. The loss of temperature in an hour's blowing, which is the almost universally adopted period, is rarely less than 200° and not infrequently reaches 300° and more. Since 100° blast temperature are equal to 3 per cent of the fuel burned at the tuyères, we see that these variations amount to from 6 to 10 per cent of fuel in the hearth. That this variable factor must necessarily produce detrimental variations in the vital part of the furnace is evident. How this variation can best be avoided or overcome the author has attempted to show in an article published in the "Iron Age," May 19 last.

With thoroughly purified gases the hot-blast stoves can readily be so constructed that they will yield a blast of very high and practically uniform temperature, which can then be readily tempered down to any degree necessary or desirable. So long, however, as iron masters will persist in using dirty gases, there is little chance of improving the hot-blast stove. The only thing to do is to make them bigger and build more of them. Why furnace proprietors should persist on these illogical and costly lines is difficult to understand. The money put into new and enlarged hot-blast stoves would nearly, if not quite, pay for an installation of gas-washing plant, which would produce much more economical and satisfactory results, as the author has shown in the paper referred to above that the blast can be readily kept at a uniform temperature by the introduction of cold blast. To do this, however, it is absolutely necessary to know the blast temperature, and it is strange to say that with a few laudable exceptions, blast-furnace managers east of the Alleghany Mountains have not availed themselves of the proper means to do this.

To have control of the heat, it is not sufficient to test the temperature once an hour, but you must be able to see what the temperature is at any moment, and what is even more important is to have an instrument which is absolutely beyond the

control of the man responsible for the temperature. An autographic record is of the greatest value. Without a positive knowledge of the temperature carried at all times, intelligent heat regulation is impossible and perfect control out of the question.

Composition of Blast. — There are few, if any, furnace managers that are not aware of the fact that humidity is an important element in the blast. Very few, however, have taken the pains and the trouble to determine what this factor amounts to quantitatively. During the period referred to above the author made hygrometric determinations and was surprised to find that the quantity of water carried into the furnace by the blast during the humid summer months amounted to tons of water in 24 hours. It is not uncommon for the air to contain 8 grains of moisture per cubic foot. At this degree of humidity a blast furnace taking 35,000 cubic feet of air a minute will therefore receive $35,000 \times 8 \div 7,000 = 40$ pounds of water vapor per minute, or 2,400 pounds per hour, or over 28 net tons in 24 hours. Since that time (1886) the author has persistently advocated the economical importance of removing this moisture from the blast, and the process of refrigeration as the best method for removing it.

Knowing the amount of moisture going into the furnace with the blast, it is easy to figure the fuel required to neutralize its chilling effect. Making this calculation we find that one pound of moisture requires in round numbers 1.3 pounds of carbon to be burned at the tuyères to replace the heat absorbed by the decomposition of the water vapor. This, in itself, amounts to a very considerable quantity of fuel during the summer months, yet it is less than 25 per cent of the actual fuel saved, as demonstrated at the Isabella furnaces by Mr. Gayley's desiccating plant.

The strictest attention is paid by every furnace manager to guard against water getting into the furnace through leaky tuyères or cooling plates, yet absolutely no regard is given to the contamination of the blast by avoidable moisture. Innumerable steam leaks are often allowed to exist in the engine-room, nearly all of the steam from which is carried into the furnace without any idea of the fuel necessary to overcome this extra moisture. So long as these leaks do not become positively

annoying to the engineer, they are rarely attended to. One instance in the writer's experience may be permissible to illustrate. At the plant in mind the blowing engines and pumps were in charge of the master mechanic of the works over which the furnace manager had no authority. Repeated requests to repair the leaky joints were ignored. Hygrometric tests of the blast showed that it contained from 5 to 7 grains of moisture per cubic foot above the outside atmosphere. Calculations based on this moisture content laid before the general manager brought the necessary pressure upon the master mechanic. The steam pipes were overhauled. The effect was an immediate reduction in the fuel consumption of 150 to 200 pounds per ton of iron. There is no doubt in the author's mind that similar fuel economies might be obtained at many of the existing plants.

In the author's estimation desiccation of the blast is a step in advance, second in importance only to the hot blast, and that it will be as generally and, perhaps, even more promptly adopted.

Chemical Reactions. — Practical furnace men are, as a rule, very much in the dark as to the chemical reactions which take place inside of the blast furnace. Accurate data, both as to the temperatures existing and changes which take place in the various zones of the modern blast furnace, are entirely wanting. Such an investigation as was carried out by Sir Lowthian Bell nearly forty years ago is very badly needed to throw light on what actually takes place in a blast furnace under the so materially changed conditions and methods of modern practice.

Every blast-furnace manager knows, of course, the nature and composition of the raw material charge at the top, and the physical condition and chemical composition of product tapped out at the bottom, and can and should know the composition of the escaping gases. And all this indicates to him more or less clearly what is actually going on inside of the furnace. But in reality all he knows with certainty is the beginning and the end. We know that all the carbon that reaches the tuyères is burned to CO, and that this reaction is the principal source of heat by which the process of smelting is carried on, and that the CO is the all-important reducing agent.

From the composition and temperature of the escaping gases we can make inferences as to the relative efficiency of the

furnace at the time. From the appearance and chemical composition of slag and iron we can tell whether the furnace is in good or bad working condition, but of the actual chemical reactions taking place in the interior of the furnace, either as to their sequence or relative importance, we know practically nothing.

Carbon Impregnation is one of the important phenomena about which we are still very much in the dark. It had been observed before, but was first prominently brought before the iron metallurgists through the researches of Sir Lowthian Bell, that sesquioxide of iron (Fe_2O_3) possessed the property of splitting up CO into $C + CO_2$ at temperatures existing in the upper region of a blast furnace. This phenomenon has recently been the subject of scientific investigation and is very ably discussed in "Stahl und Eisen," Nov. 21, 1904, by Dr. Aloys Weiskopf.

All hematite ores possess this quality to a greater or lesser degree, and some of these from the Mesabi range are most remarkable for their capacity to become impregnated with carbon.

Experiments conducted by Mr. O. O. Landig * showed that the ore of some of the deposits became impregnated to such an extent that their volume was very considerably increased. This being so, it is more than probable that most of the difficulties experienced in smelting the Mesabi ore are due to this quality of excessive carbon impregnation.

Hanging of the Stock in the upper part of the furnace is, no doubt, entirely due to this phenomena, for it necessarily follows that the swelling of the ore must increase the resistance to the gas currents and must also increase the friction against the inwall of the furnace. Now, if we consider that even under the most favorable conditions by far the greater part of the column of stock is supported by the normal friction against the inwall, and the further fact that 1 pound of unbalanced gas pressure will sustain approximately 1 foot in height of the column of stock, it is not difficult to understand how the downward movement of the solid material may be arrested without involving any other factor than excessive carbon impregnation.

* "Transactions of American Institute Mining Engineers, Vol. XXVI, "Action of Blast-Furnace Gas on Various Iron Ores."

A portion of the stock column having once come to rest, it is bound to remain at rest until the cause of arrest is removed. This necessarily follows from the fact that friction of rest is greater than friction of motion, so that if there is sufficient friction and pressure developed to cause a moving body to come to rest, there is always more than necessary to hold it stationary. Meanwhile, the consumption of fuel continues at the tuyères in accordance with the volume of oxygen forced in by the blast. The iron sponge is carburized and melted, the dross of both ore and fuel combines with the flux and is fused into a liquid slag which descends with the iron into the hearth, where they take up very little space compared with their original bulk, and from which they are tapped off from time to time. As this process of smelting goes on, that portion of the column of solid material which is free to move in the furnace shaft above continues to descend. This causes a break between the arrested and moving part of the stock column. A cavity is soon formed which continues to increase in dimension in proportion as the moving column is smelted and consumed. The shorter this column gets, the less is the resistance it offers to the ascending gases, hence, with a given blast pressure, the pressure in the cavity must also increase, thus giving the stationary column still greater support.

Slipping. — On the other hand, it is evident that since no cold stock enters the furnace during the period of hanging, its contents must become hotter and hotter; also that the increased temperature will accelerate chemical reaction. Reduction progresses more rapidly; the carbon deposited at the lower temperature is consumed by the oxygen, liberated from the ore which it had impregnated, or by reducing CO_2 to CO, probably both. As this process proceeds, the stationary column necessarily shrinks, gradually loses its hold on the wall, and finally breaks away. This phenomenon is called a slip or slipping.

There are two distinct varieties of this phenomenon, the one due to causes just discussed, known as top slips, always occurring in the upper half of the stock column; and the other, called bottom slips, to which I shall recur later, due to causes entirely different and always occurring in the lower part of the furnace, generally within the limits of the hearth and bosh.

To have a furnace slipping is always unpleasant. It is

frequently serious and on several occasions resulted very disastrously.*

Prior to the introduction of the Mesabi ores, top slips were of very rare occurrence, and when they did occur were of a comparatively mild form, but no sooner had these ores become an appreciable part of the ore mixture than these phenomena of slipping became more and more frequent and very often manifested themselves with such force that "explosion" seemed to be a more appropriate term than "slip," and hence the phenomena is generally referred to as "Mesabi ore explosions."

When we consider that the dislocation of the charging hopper and top plates was an every-day occurrence and that on several occasions the whole charging apparatus, weighing many tons, was blown clean off the furnace and large quantities of stock were scattered broadcast, it appears quite natural that the explosion hypotheses should have seemed necessary to explain the effect produced.

On the other hand, a little calculation will show that the force necessary to throw a bell and hopper out of a furnace is not so great as would appear from the mere statement of the fact that they weigh many tons. A gas pressure of 1 pound per square inch, when applied to a circular area 12 feet in diameter, exerts a lifting force of considerably over 8 net tons, and on an area of 14 feet in diameter, of fully 11 net tons. This is quite sufficient to lift the average bell and hopper out of place.

What pressure of gas is produced by a top slip depends on the size and the shape of the cavity developed during hanging, as well as the temperature and pressure of the gas it contains, the weight of the suspended column and the manner in which it drops. There being no means of making direct observation, we can only reason from effect to cause, and the severity of the former has given rise to the assumption that the latter must be some form of explosion. Whether this view is tenable or not depends entirely on how broadly we define the term "explosion." In reality it matters little by what name we

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* It will be remembered that Captain Jones lost his life by being enveloped in white-hot coke, slag and molten iron, bursting forth from one of the Edgar Thompson furnaces in consequence of a bottom slip, and that Ed. Reisse was burned to death by the hot stock thrown from a furnace in his charge at Newcastle, Pa., due to a top slip.

call it so long as it does not lead us to a wrong conception of the phenomena of which we are endeavoring to get a clear idea and find an adequate and rational explanation.

Let us suppose that the upper ten feet of the stock in a modern blast furnace becomes arrested, *i. e.*, hangs. The furnace working normally below, a cavity will at once begin to form, and will increase as fast as the descending column is consumed at the lower end by the process of combustion and smelting. As the descending column shortens, the resistance to the ascending gases through it becomes less, and since the condition of the hanging column is but slowly changing, the gas pressure in the cavity steadily increases. The same is necessarily true of the temperature, since the gas passes through material which is getting hotter and hotter as it approaches the zone of fusion. While the increased pressure tends to support the hanging column indefinitely, the increased temperature stimulates chemical action referred to above, and the deposited carbon is gradually consumed. This burning out of the impregnated carbon causes shrinkage of the suspended material and finally results in its dropping or slipping into the cavity below.

It does not require any very considerable stretch of the imagination to suppose that the hanging column, which we assumed to be 10 feet high, drops like a practically solid plunger into a cavity below, 10 or 15 feet deep. This cavity being filled with highly heated gas already under considerable pressure, the necessary immediate effect would most likely be as follows: The hot gas below will be compressed proportional to the weight and momentum of the descending mass, and the partial vacuum formed above will be filled by cooler gas rushing back into the furnace from the gas mains, mingled with more or less atmospheric air drawn in through the leaky bell and poorly fitted explosion doors. Immediately the pressure of the compressed gas is sufficient to overcome the resistance offered by the plunging stock column; it breaks through with force and instantly mixes with the cooler gases above, raising them suddenly to a high temperature, which later may be very materially augmented by the instantaneous combustion of the oxygen present, resulting in a pressure sufficiently sudden and high to produce effects akin to real explosions. The author is not aware that the pressures of these so-called " explosions "

have ever been measured, but it is doubtful whether they often exceed 10 or ever reach 15 pounds per square inch. The lesser of these pressures would be quite sufficient to throw any bell and hopper not securely fastened down, clean out of the furnace.

It must not be supposed that top slips always take place in the extreme manner of our hypothetical case just described. Generally the hanging stock drops into the cavity below less suddenly, the phenomena lasting over many seconds and sometimes minutes; nevertheless, considerable quantities of fine ore and coke are thrown out with every slip, and not infrequently large quantities of the coarser material, especially coke, as well. The large furnaces, working principally on Mesabi ore, apparently work by slips only. It is the exception rather than the rule that 24 hours pass without appreciable slipping. The quantities of coke and ore that are frequently blown out through the explosion doors and scattered over the premises are appalling. There is one feature about these phenomena which, since their destructive effects have been overcome by structural improvements, makes them less objectionable than would at first appear. The real process of smelting is but very little, if at all, disturbed by them. If it were not for this fact, top slipping would have become intolerable long ago. As it is, large output and acceptable quality are still attainable.

In the light of our present knowledge, top hanging and slipping seems to be attributable to two causes: first, the inherent condition of the ore, and, second, over-exposure. The first can be mitigated by judicious selection and admixture of the ores and proper charging, and the second cause can be largely, if not altogether, avoided, by smelting these ores in furnaces better adapted to their requirements. The modern excessively high furnace is an absurdity when we consider reducibility and other properties, both physical and chemical, of the ores smelted in the majority of them.

Bottom Slipping. — Bottom slipping is a phenomenon quite different from top slipping, and it is due to entirely different causes. Bottom slipping occurs entirely within the zone of fusion and is chiefly caused by temperature variations due to direct variations in the blast temperature, the irregular moisture content, and to changes in the carbon content in the fuel. Irregularity in the composition of the slag aggravated by tem-

perature changes is probably the most prolific cause of hanging and slipping in the lower part of the furnace. Excessively basic slags are more inclined to build up than acid slags. High alumina slags are especially bad. Bottom slips invariably spoil one or more casts of iron, and not infrequently block up the hearth and tuyères to such an extent with a cold refractory conglomerate of partially reduced iron, slag, carbon dust, lime and fine coke, that heroic means are required to get the furnace into proper shape again. Not more than a generation ago these bottom slips very often proved fatal to the campaign, or at least required days of sledging and drilling, to get the blast properly into the furnace and the molten iron and slag away from it. The introduction of the oil blow-pipe proved itself of great assistance to the troubled furnace manager, and latterly the electric arc makes playwork out of the task of opening up frozen tuyères and chilled iron and cinder notches, compared with the sledge and chisel of the olden days.

Scaffolding. — When the accumulations which give rise to bottom slipping cease to come off, *i. e.*, become chronic, we have scaffolding. There can be no doubt that all scaffolding starts in the zone of fusion, and is due to the causes that give rise to bottom slips. If that is true, what would prevent the latter would make the former impossible. Whether these disturbances can ever be entirely overcome may be questioned, yet there is still so much room for improvement in furnace practice, *e. g.*, in the preparation of the ore and flux, the selection of the fuel, the manner of charging, uniform blowing, desiccation and regular heating of the blast, etc., that many of the troubles now of still too frequent occurrence may be almost, if not entirely, eliminated.

Mechanical Conditions

Distribution. — The proper distribution of the stock is one of the most important factors in the operation of the modern blast furnace, and this has been greatly emphasized since the introduction of the automatic charging apparatus. There are few conditions in connection with the designing and management of the modern blast furnace that have given so much trouble and worry to the engineer as well as the furnace manager. While much has been done to overcome the inherent

tendency of the skip-hoist to distribute the coarse and fine ore unequally, and much improvement has been made, the charging device that will distribute all the different kinds of material satisfactorily has not yet been invented; or, if invented, has yet to demonstrate its practicability and effectiveness.

The ideal charging apparatus, in addition to fulfilling the paramount requirements of being strong, durable and forming perfect gas-seal, should be under such control of the man in charge that the material charged, irrespective of its physical condition, can be distributed from the hopper evenly over the entire area of the furnace or practically in a ring against the outer wall, all in the center, or in intermediate circles; or, if need be, in a heap in any desired point of the compass. With such a charging apparatus many of the difficulties now encountered would be entirely avoided, and such irregularities in the settling of the stock which might still occur could be speedily remedied. To be able to use such a charging apparatus to its full possibility it should be supplemented by an automatic stock-level indicator.

Whether the above ideal will ever be reached, or even approximately realized in practice, may be questioned; but there can be no question as to the shortcomings of all existing apparatus. The bell and hopper which fulfills the first three requirements perfectly falls far short as a distributor because of its narrow limitations and inflexibility, especially in connection with the automatic skip-hoist.

When filling is done by hand it is generally possible, by exercising proper care and judgment, to distribute the stock in a manner most conducive to good results. All the ores should be separated into at least two classes physically, viz., coarse and fine. At hand-filled furnaces this can generally be accomplished without special apparatus, and the stock can be charged into the furnace in accordance with any method the manager may desire, within the limits of the apparatus, which allow great variation, and in this way much can be done to secure uniform working, provided there is sufficient intelligence and vigilance available on the stock-house floor.

Barrows' Method of Charging

This method was described by Mr. Barrows, Jr., before the Atlantic meeting of the American Institute of Mining Engineers, and may appropriately be called heterogeneous charging.

Assume, for example, that the ore mixture consisted of 25 per cent of magnetic concentrates, 25 per cent of fine hematite, 25 per cent of coarse hematite and 25 per cent of coarse magnetite, and that a round of ore consisted of 12 barrows.

On this assumption (using the points of the compass for convenience of explanation) the charging would proceed as follows: The coke charge having been lowered into the furnace, then, starting in the north, fill 3 barrows of concentrates side by side, in the northeast quarter; next 3 barrows of coarse hematite, in the southeast quarter; then 3 barrows of fine hematite in the southwest quarter; completing the round with 3 barrows of coarse magnetic ore in the northwest quarter of the hopper. The next round would start in the east with 3 barrows of concentrates above the coarse hematite, next 3 barrows of coarse magnetic ore over the fine hematite, then 3 barrows of fine hematite over the coarse magnetic ore, closing with 3 barrows of coarse hematite over the concentrates. Thus getting every ore into every part of the furnace in regular routine, the coarse and fine ores alternating both as to their vertical and horizontal relation. The main object of this method of filling being to break up the continuity of the gas currents and thus prevent channeling, reduce flue dust and obviate irregularities in general. Mr. Barrows has practiced this method with very good success. It is applicable to all hand-filled furnaces, and could be adopted with advantage by all furnaces having to smelt ores differing very much in degrees of fineness.

Uehling's Method of Charging

Prior to the advent of the closed furnace tops it was the universal practice to mix the fuel and its burden as much as possible. Every barrow of fuel was invariably followed by a barrow carrying its quota of ore and flux. This method was continued as much as possible after the general adoption of the bell and hopper. At the works in Sharpsville, Pa., where

the author first made his acquaintance with the blast furnace in 1879, the fuel charge consisted of 2 barrows of block coal of 500 pounds each, and 2 barrows of coke weighing 300 pounds each, a total fuel charge of about 1,600 pounds. The 2 barrows of coal were dumped into the hopper opposite, and the two barrows of coke into the gaps left between them. Four barrows, of which each carried its proportion of ore and limestone, were dumped over the fuel and all were lowered into the furnace together, thus mixing fuel and ore as much as possible. After studying "Bell's Phenomena of the Blast Furnace," and particularly "Gruner's Analytical Studies of the Process of Smelting," the author came to the conclusion, based entirely on theoretical reasoning, that it was all wrong to mix the ore and fuel in charging a blast furnace; that, on the contrary, they should be separated as much as possible in order to obtain the best results. The theoretical reasons, both chemical and physical, why this should be so, were fully set forth in a paper published in the "Stevens' Institute Indicator," in 1884, and again alluded to in my contribution to the discussion of Mr. Barrows' paper read before the spring meeting of Mining Engineers at Atlantic City, so that it will not be necessary to repeat them here. Briefly, the method of stratified charging consists in filling the fuel and ore in separate layers. The fuel charge should be as heavy as is consistent with the size of the furnace, forming uniform strata not less than 2 feet deep. In a furnace over 80 feet high, preferably deeper, the ores should be filled on the fuel in strata, beginning with the coarsest and ending with the finest. The limestone, being coarse, should go on top of the strata of coarse ore. It should be kept as much as possible from coming in direct contact with the fuel. Different ores of the same degree of fineness should be charged with regard to their capacity for carbon deposition. This very important phase in the phenomena of smelting was very ably discussed by Mr. F. E. Bachman in a paper read before the Colorado meeting of the American Institute of Mining Engineers, but has not received the attention it deserves. In how far the method of charging above briefly outlined can be carried out in practice depends on local conditions, which would have to be studied on the premises in each case. It may safely be said, however, that there are few furnaces the running of which

could not be very appreciably improved by the application of stratified filling. It can be carried out equally well by hand or any of the approved automatic filling devices.

Gas. — The blast-furnace gas is a most important factor in the process of smelting, not only inside, but also outside of the furnace. Inside of the furnace it distributes the heat and reduces the ore to the metallic form. How well it performs these functions can always be ascertained from its temperature and chemical analysis. The first symptoms of irregularities in the process of smelting manifest themselves in the gas. A continuous record of the CO_2 would be of the greatest value to the observant blast-furnace manager. The continuous autographic record of the gas temperature has been found by those who give it attention to be an invaluable aid in diagnosing irregularities in the working of the furnace.

Every furnace man knows that a hot top is indicative of a cold bottom. This will be readily understood from the fact that 100 degrees of heat in the escaping gas is equivalent to over 4.25 per cent of the heat generated by the fuel burned at the tuyères. Thus, an indirect fuel loss of from 10 to 15 per cent may easily take place unnoticed until four or six hours later sharp cinder and inferior iron reveals the fact that something went wrong.

In addition to revealing internal conditions of the furnace, the autographic gas temperature record indicates the charges that go into the furnace, both as to time and number, and is, therefore, a most valuable check on the stock-house operation.

In a paper entitled " The Blast Furnace as a Power-Plant," the author endeavored to show by simple process of calculation that, under conditions of best average fuel consumption, viz., 2,000 pounds of coke per ton of iron, and proper treatment and utilization of the gas, there would be a surplus of at least 800 horse-power per ton of iron produced per hour. Or, in other words, a blast furnace of a daily capacity of 250 tons, or, in round numbers, 10 tons per hour, should have a surplus of gas, over and above all furnace requirements, sufficient to generate 8,000 horse-power in any of the available types of large gas engines. Other investigators,* notably Mr. B. H. Thwait, who is the pioneer in the field of direct utilization of blast-furnace gas in the gas engine, have come to similar conclusions.

Since publishing the above calculations, the author has had opportunity to investigate the blast-furnace gases at a number of the large iron and steel plants, and has found that his figures were very conservative; that from 1,000 to 1,200 horse-power is nearer the actual surplus power that should be available.

In view of these facts, and the practically more weighty fact that on the continent of Europe, especially in Germany, there is scarcely a furnace plant where from several to many thousand horse-power are not generated by blast-furnace gas direct, is it not strange that, with one laudable exception, nothing at all has been done to save the enormous waste now going on because of the irrational application of the blast-furnace gas?

From 45 per cent to 50 per cent of the heat value of the fuel used in the process of smelting in the blast furnace is contained in the escaping gases, of which 35 per cent should be sufficient to heat the blast and produce the power to run the furnace and all its mechanical accessories. In spite of this enormous theoretically demonstrable surplus heat energy, the fact remains that, at the majority of the blast-furnace plants, hundreds of tons of coal are burned annually to assist the gas in generating the necessary steam for the power required, and it is the exception rather than the rule that the desired blast temperature can be regularly obtained from the stoves, notwithstanding the fact that both stoves and boilers have, from time to time, been increased both in size and number. The sole reason of this deplorable condition is due to the fact that the uncleaned gas cannot be efficiently utilized. It is just as irrational to burn the impure gas as it would be to attempt to burn coal mixed with all the slate and rock that is dug and raised with it from the mine.

The partial purification employed at the majority of plants in the dry way is based on irrational methods and carried out by primitive and inadequate means, and rarely more than the coarsest of the flue dust is separated from the gas. The attempts at washing are generally carried out by half-way methods, which, although they remove much of the finer dust, are liable to contaminate the gas to such a degree with moisture that the harm overbalances the good accomplished.

The subject of gas purification is too vast to do more than allude to it at this time. I consider it the most important problem before the blast-furnace manager and engineer to-day. Even if we leave out of sight the value of the surplus gas for power purposes, the saving in extra boiler and stove equipment, in wear and tear on the latter, in time lost directly and indirectly because of stoppages for cleaning, inadequate steam and heat, coal burned, and cost of labor for cleaning stoves and boilers, etc., etc., would more than justify the cost of a gas-washing equipment that would properly cleanse the gas.

THE CASE OF HENRY CORT *

By CHARLES H. MORGAN

THE case of Henry Cort comprises: (1) The nature of Cort's inventions; (2) their value to England and to mankind; (3) the remuneration received therefor by him or his family; and (4) the suitable permanent record and recognition of his services by the representatives of the art he founded — a debt long overdue, and still unpaid.

I. Cort's Inventions

Under this head, it is unnecessary here to enter into details. The facts have been repeatedly published,† and a brief outline of them will be sufficient for my present purpose.

Henry Cort, born in 1740, at Lancaster, England, became a

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* Read at the Lake Superior meeting of the American Institute of Mining Engineers, September, 1904.

† See Cort's British patents Nos. 1351 (of 1783) and 1,420 (of 1784); also, a series of articles by Thomas Webster, an eminent authority on Patent Law, in the "Mechanics' Magazine," Vol. II, London, 1859; Percy's "Metallurgy," "Iron and Steel," London, 1864, pp. 627–639; "Memoirs of Distinguished Men of Science," London, 1864, p. 152; Smiles's "Industrial Biography," London, 1897, p. 114; Facts and Proofs Collected by R. Cort, London, 1855; and a partial summary, in my Presidential Address, "Some Landmarks in the History of the Rolling-Mill," delivered before the American Society of Mechanical Engineers, at the New York meeting in December, 1900, and published in Vol. XXII of the Transactions of that society.


IN MEMORY OF
HENRY CORT
BORN AT LANCASTER 1740
INTERRED AT HAMPSTEAD 1800
TO WHOM THE WORLD IS INDEBTED
FOR THE ARTS OF REFINING IRON
BY PUDDLING WITH MINERAL
COAL AND OF ROLLING METALS
IN GROOVED ROLLS.

navy broker in London about 1765, and gained from that business in about ten years something more than £20,000, which he devoted to perfecting the manufacture of iron, building a mill at Fontley, near Portsmouth, and prosecuting, between 1777 and 1783, the experiments which culminated in his two patents, one for puddling iron and the other for shaping it by rolling between grooved rolls. Careful study of the contemporary evidence, including Cort's specifications, the testimony (in act as well as word) of his business rivals, the public declarations of eminent authorities, and the history of the times, leaves no possible doubt that Cort was the real inventor of these two inestimable improvements. Every such invention is subject to claims of priority advanced in behalf of unsuccessful predecessors. The relative rights of such claimants to the sentimental credit, so to speak, of a given step of progress, may be difficult of adjudication; and sometimes the suggester of an idea which he never effectively executed may deserve praise and thanks for his incomplete achievement; but the principles of both English and American patent law make short work with such pretensions. That law was not instituted to reward prophetic genius or intuition. It rests upon the proposition that a man who has discovered and successfully practiced an improvement in the arts, and who might possibly keep it as a trade-secret, to die with him, shall be induced, by the grant of a monopoly for a limited term, to tell his secret completely to the public, so that, after the expiration of that term, any expert in the art concerned may be not only entitled but enabled to practice it. It is a question, not of recognizing meritorious aspiration or endeavor, but of buying for public use an actually successful device. Much credit is often fairly due and freely given to unsuccessful inventors who have, nevertheless, no rightful claim to the reward of a patent-monopoly.

In the case of Cort, Dr. Percy mentions one or two prior inventors,* discovered by his researches, who seem to have been

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* As to puddling, Thomas and George Cranage (British patent No. 851, of 1766) and Peter Onions (No. 1,370, of May, 1783). Since Cort began experimenting in 1777, the date of the latter is not proof of priority of invention. There is no evidence that either of them was commercially practiced. Concerning the use of grooved rolls, I think Cort's originality is not denied.

working on the same lines, and to some extent with the same general ideas. But they do not seem to have put their ideas into practical use. The malicious and false testimony, denying the practical merit, and thus the patentable character of his inventions will be briefly alluded to later. It does not deserve serious consideration here. On the whole, it may fairly be said, that beyond all honest doubt and by substantially universal acclaim, Henry Cort was the first to perfect, put into successful operation, give to the world by sufficient description, and teach to other operators, his licensees, the puddling of iron and the rolling of puddled iron between grooved rolls.

II. The Value of Cort's Inventions

As I have already observed, Henry Cort accumulated a fortune of more than £20,000 as a navy broker, furnishing supplies for the British navy, at a period when England stood at bay, fighting for her colonial possessions in North America, and almost for her own national existence, and when the power and prowess of her navy was her chief, if not her only, reliance. Yet no forge or furnace in England could make iron fit for navy use. The nation, though endowed with vast deposits of iron ore and of coal, was dependent upon the purer raw materials of Sweden and Russia for wrought iron of good quality; and the Admiralty specifications called for Swedish or Russian iron. While Cort was in business as a navy broker, the demand for these foreign irons increased the price nearly 200 per cent. What was even worse, the dependence of England upon this foreign supply might possibly, at any moment, become a source of fatal weakness in war.

No doubt it was the perception of this critical situation which stimulated Henry Cort, both as a patriot and as an intelligent inventor, to risk his entire fortune and future upon the attempt to render his country independent of the world in a particular so essential to her prosperity. And the result of his enterprise may fairly be said to have altered profoundly the history of the world. Before 1785, England paid annually to Sweden alone £1,500,000 for wrought iron. As the "London Times" * has said:

* July 29, 1856.

"Then came the war, commercial embarrassment, depreciated paper, foreign prohibitions and an overpowering and increasing demand for more and more iron. The inventions of Henry Cort carried us easily through this period of sharp trial, and, as his descendants allege, were the principal cause of our success."

A single instance may show how great was the revolution effected by Cort's improvements. Richard Crawshay, one of the first of Cort's licensees, who was making under the hammer barely 10 tons of bar iron per week, increased his product by the process (concerning which he wrote, "I took it from a Mr. Cort, who had a little mill at Fontley, in Hampshire") to 200 tons per week. But more significant still is the fact that, after the introduction of Cort's inventions, the Admiralty specifications, instead of excluding English iron, called for it.

Lord Sheffield said in 1786, only two years after the date of Cort's second patent:

"If Mr. Cort's very ingenious and meritorious improvements in the art of making and working iron, the steam-engine of Boulton and Watt, and Lord Dundonald's discovery of making coke should all succeed, it is not asserting too much to say that the result will be more advantageous to Great Britain than the possession of the thirteen colonies of America."

And in 1865, nearly eighty years later, William Fairbairn said:

"Henry Cort's inventions have conferred an amount of wealth on Great Britain equal almost to six hundred millions sterling, and have given employment to six hundred thousand men."

The prophetic declaration of Lord Sheffield, quoted above, suggests another element in the military and commercial triumph of England which demands recognition — namely, the steam engine of James Watt. The wonderful results of this improvement upon the Newcomen engine, first applied to hoist water from mines, have been abundantly, yet not too abundantly, celebrated. At various places in England, there are statues and memorials — half a dozen, at least — in honor of Watt; and another is projected, to be erected by British and American engineers, under the lead of Mr. Carnegie. They are not too many; he deserves them all. But it should not be

forgotten that his friend Henry Cort furnished the most immediately — and perhaps, we might even dare to say, the most permanently — important use for the steam-engine.*

For what other application of that great motor can be deemed, even to-day, more important than the manufacture of the material of which itself consists, and through which in countless forms and ways, its benefits are conferred upon men?

It would be ungrateful, as well as unjust, in setting forth the merits of Cort, to diminish in the least the credit and fame of Watt; for the appreciation and sympathy of Watt were of value untold to Cort, in his misfortunes, though these were of a sort which Watt himself had never been called to encounter. We are now considering, however, simply the value of Cort's two great inventions, not his personal experience; and on this point

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* Mr. Charles H. Loring, in his Presidential Address before the American Society of Mechanical Engineers (1892), paid an eloquent tribute to the steam engine, declaring it to be the great underlying cause of the wonderful progress of the last 100 years, and adding, " It is what no other machine ever was, the creator of physical power. The immortal inventor died without dreaming that he had placed on earth an infant Hercules, whose club, with an ever-increasing might, would batter down the institutions of preceding ages."

I cannot do better than repeat here, from my address on the history of the rolling-mill, delivered eight years later, and already cited in this paper, my comment upon this passage in Mr. Loring's address:

" I endorse that tribute, with this distinction only: Watt's engine is the Hercules; but the rolling-mill is his club! Disarm him; take his club away — and how little, with his vast strength, can he do! The steam engine may be ' what no other machine ever was, the creator of physical power'; but the rolling-mill has ever been the creator of the harness for using that power."

Discarding poetic expression, we must, of course, confess that the steam engine does not create, but only liberates and transforms, the power already existing, latent, in the fuel it consumes; while the rolling-mill further transforms the same power into the molecular movement and consequent change of form of the metal it treats. But such comparisons serve no useful purpose. The overwhelming, providential fact is, that just at the time when Watt's steam engine achieved recognition, Cort gave it the means of its most stupendous achievement, in driving a rolling-mill, and thereby inaugurating the most profound industrial revolution recorded in human history. Not steam alone, but steam and iron have wrought that revolution.

what I have already said may suffice, since it has been amply corroborated by the highest authorities.*

III. Cort's Reward

This chapter also I shall make as brief as possible. Not long ago, I printed, for private circulation only, a "Review of the Case of Henry Cort," which I shall be glad to furnish to those who are seriously and sufficiently interested in its details. Here I shall confine myself to a bare statement of the essential facts.

1. For the purpose of obtaining additional capital, Cort made a business agreement with one Adam Jellicoe, a deputy paymaster in the navy, whose son Samuel he admitted to a partnership in his business, in consideration of which the father advanced to the firm considerable sums of money, taking as collateral security for Cort's share in the firm's debt, an assignment of Cort's patents. The arrangement was fair enough on its face; but the moneys advanced under it by Adam Jellicoe had been stolen from the government funds, with the collusion of the treasurer, Mr. Dundas, afterwards Lord Melville. That Cort had any knowledge of this circumstance there has never been either proof, accusation or suspicion.

2. The embezzlements of Adam Jellicoe had been carried on for years with the knowledge of the treasurer and his paymaster, one Trotter; but in 1788, under the pretense of a claim for repayment, these two forced him to surrender to them the Cort patents, which he held as collateral. Soon after (in 1789), Adam Jellicoe died; Lord Melville and Trotter instantly "discovered" his defalcation; and the latter, by a false affidavit, obtained an "extent" or summary attachment upon Cort's whole business and property.

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* In addition to Percy and Webster, already cited, I may mention here the Duke of Devonshire, in his inaugural address at the first meeting of the Iron and Steel Institute in 1869 ("The Iron and Steel Institute Transactions," Vol. I, p. 5); Sir James Kitson ("Journal of the Iron and Steel Institute," 1890, p. 392); Sir Lowthian Bell (*Ibid.*, p. 422); Sir William Roberts-Austen (*Ibid.*, 1899, p. 21), and Mr. Andrew Carnegie ("Iron Age," October 27, 1904, p. 45), — five presidents of the Iron and Steel Institute (and Dr. Percy makes six), the body best qualified to give judgment in such a case. In fact, there is no difference of opinion on the subject among competent experts.

3. At that time, the amount of the alleged defalcation of Jellicoe, for which Cort was thus arbitrarily made responsible, was only £27,500. Cort was then executing a navy contract for £15,000; and was receiving in royalties £15,000 per annum. Yet Trotter swore that he verily believed the said Henry Cort to be "much decayed in his credit and in very embarrassed circumstances," so that his Majesty could not recover "the aforesaid debt" without more speedy means than the ordinary process of the court. Accordingly, Cort's property was seized.

4. After this seizure, the patents were never seen; the contracts with licensees likewise disappeared; and so far as can be discovered, no royalties were ever collected under them. These royalties alone would have repaid the whole of the alleged defalcation within two years. But nothing was done to administer the property; and Cort was thus at one blow deprived without redress of all his earthly possessions, — forge, mill, patents and royalties; in a word, completely ruined.

The amount of the royalties already covered by agreements would have amounted, at the date of Cort's death, to £200,000. If Lord Melville, who confessed the possession of the agreements, collected any part of this sum, he never accounted for it to the government.

5. Cort patiently sought to obtain justice, apparently without understanding the influences at work against him. He petitioned Trotter! he petitioned the Commissioners of the Navy; he petitioned Parliament; but was treated with indifference or insult. In 1794, a petition was addressed to the Prime Minister, William Pitt, praying that Cort might be appointed to some position in one of his Majesty's dockyards, or otherwise mercifully treated. This appeal brought a pension, netting him about £150 a year. After his death, his widow received net £100 a year, and later, on her decease, the two unmarried daughters received per annum £25 6*s.* each, "subject to reductions," or probably about £20. And this was doled out to a man from whom the government had taken more than £200,000, to repay a defalcation of £27,500, of which he was never even accused of having any knowledge!

But the greatest outrage was yet to come. In 1800, Henry Cort died; and as soon as he was out of the way, and his infant children were incapable of asserting their rights,

Lord Melville presented a memorial to the Lords of the Treasury, setting forth the great merit and value of Cort's inventions, and asking on that account that *he himself* should be released from £25,000 of the Jellicoe defalcation, for which he held himself responsible! This petition was promptly granted; and presumably the Cort patents were turned over to the government and canceled.

6. In 1803, Parliament appointed a Commission of Inquiry to examine the irregularities of the Treasurer, Lord Melville, and his Paymaster, Alexander Trotter; but these two worthies burned their accounts before they could be examined. The documents in the Cort case were destroyed with the rest. Upon his impeachment and trial (the amount of the defalcation of £25,000 having been made good in 1800, as stated above), Lord Melville was acquitted by a vote of 88 to 47 peers! In other words, a high official of the British Government had stolen money from its treasury; the government connived in his attempt to shield himself by robbing an innocent citizen, under the forms of law, abominably misused for that vile purpose; not only the patent rights which the government had solemnly covenanted to protect, but also all other property of the innocent victim, were thus stolen from him by arbitrary process and without legal redress; and finally, as a climax of this performance, the original thief was rewarded, in consideration of the great value of the plunder, of which the Government of Great Britain then became the receiver!

7. It seems justly clear, however, that the government treasury received no pecuniary benefit from this crime. It had been robbed by Lord Melville; and it credited him with the value of the proceeds of another robbery, which he transferred to it; but, so far as can be discovered, it did not realize any part of this value by collecting from Cort's licensees the royalties they were pledged to pay. Consequently, the beneficiaries of the outrage, next to the titled criminal (and to a far greater pecuniary extent), were those who were thereby released from the payment to Cort of the royalties (amounting to $1,000,000) which they had agreed to pay him, and, next to these, the manufacturers, who, during the term of Cort's patents, used his inventions without even agreeing to pay royalty, and were never called upon for such payment. In view of the rapid extension

of the practice of these inventions, thus prematurely thrown open to the public in total disregard of the inventor's guaranteed rights, it is a safe estimate that $2,000,000 more was saved to somebody. Whatever may have been the injustice of the summary proceeding by which Cort was robbed and ruined, it was clearly the duty of the government, as the holder of the patent rights and other property which it had seized, to administer them, and account for the resulting revenue. There is not the least trace that this was ever attempted; and in view of the revealed character of Lord Melville (which the whitewash applied by the peers cannot hide), it is hard to believe that immunity from those payments of royalty under Cort's patents, which he could have enforced, was not bought from him by bribery.

Unfortunately, there is evidence, confirming this suspicion, of shameful treachery and falsehood on the part of some of the ironmasters who apparently profited by the remission of royalties and the practical cancellation of the Cort patents. In 1812 a petition for a parliamentary grant to Cort's family, in reward for his services to his country, was presented in the House of Commons, with a recommendation from the Prince Regent. It was referred to a committee, of which the son of Lord Melville was a member. Two ironmasters were heard against the petition. Their evidence could have been easily overthrown; but the committee, excluding all evidence in contradiction or explanation of their statements, suddenly closed the investigation, and reported to the House that, though a considerable share of merit was due to Henry Cort, they could not satisfy themselves that it was sufficient to entitle the petitioner to a parliamentary reward.

The testimony of the two false witnesses aroused much public indignation; and within a few weeks after the inquiry the chairman of the committee received a mass of evidence, concerning which he calmly said that "if it had been in time, the report of the committee would have been very different." Yet the children of Henry Cort were never able to get this evidence further considered. Even the recommendation of the committee of a grant to cover the expense of their futile petition for justice was ignored; and this amount was calmly charged against their penury.

8. The last chapter in this long story of wrong is the petition of Richard, the only surviving son of Henry Cort, presented to Parliament in 1856. Direct result it had none, so far as I know; indirectly, it was probably the cause of the grant to Richard Cort by Lord Palmerston, then premier, of an annuity of £50 (all previous Cort annuities, with their "reductions," having lapsed).

In connection with this revival of the question, several interesting publications appeared.*

IV. Our Unpaid Debt to Cort

Samuel Smiles, in his biography of Cort, says:

"While the great ironmasters, by freely availing themselves of his inventions, have been adding estate to estate, the only estate secured by Henry Cort was the little domain of six feet by two in which he lies interred, in Hampstead churchyard."

During a recent visit to England, I tried to find that "little domain." The sexton of the church knew nothing about it; but after the entry of the burial had been found by examination of the records, a renewed search discovered at last the grave. The headstone was weather-worn, and the inscription upon it hardly legible. It seemed as if inanimate things had conspired to perpetuate the obscurity and neglect wrought by the malice of man.

I have had this stone cleaned, and have obtained permission from the parish authorities to place in the Hampstead church a bronze tablet in honor of Henry Cort, which is represented in the illustration, from a photograph of the plaster cast. The head is of life size.

When our English brethren are ready to erect the larger monument which Henry Cort deserves, no doubt we shall all be glad to coöperate with them. Meanwhile, one American, at least, has had the opportunity and privilege of expressing in an enduring form, for the encouragement of other meritorious though defeated heroes, the assurance that, sooner or later, his-

* Among them, the article in the "London Times," of July 29, 1685, already cited, and the "Statement of the Claims of the Surviving Members of the Family of the late Henry Cort for National Compensation," issued by the Cort Committee, of which James Booth, LL.D., F.R.S., was chairman.

tory will do them justice, and succeeding generations will not let them be forgotten.

Secretary's Note. The tablet in honor of Henry Cort, to which Mr. Morgan here refers, was exhibited at the Engineers' Club, New York City, before being shipped to the Hampstead church, for the wall of which it was destined. — R. W. R.

DRY AIR IN THE BLAST FURNACE *

THE discussion aroused by James Gayley's paper descriptive of his dry-air process shows no signs of dying out, and we now present our readers in condensed form with some more German opinions on the subject, communicated to "Stahl und Eisen."

Was the Furnace Running Badly when under Natural Blast? — Professor Osann in a long article of a very theoretical nature contends that a coke consumption of only 1,726 pounds per ton of iron cannot be maintained, and he can only explain Mr. Gayley's figures by the supposition that the installation of refrigerating machinery permitted a badly running furnace to work better by increasing the production. To show that the furnace was not running well he points to the large loss by slips and to the low output as compared with other furnaces (notably Edgar Thomson) in the same district. His conclusion is that the introduction of refrigerating machinery into furnace practice would not be economically justifiable, except, perhaps, for the manufacture of some special ferro alloy requiring a very high temperature at the tuyères, to be obtained regardless of cost, a case which is very unlikely to arise with the modern facilities for producing high blast temperatures.

The idea that the furnace was running badly during the period of natural blast is upheld by other writers in our contemporary, one of whom contends that the coke consumption during this period was much too high, when the percentage of metallic iron in the charge and the grade of iron produced are taken into account. He contends that not more than 3 or 4 per cent of the saving in coke is due to the dry blast, the other

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* "The Iron Age," March 30, 1905.

16 or 17 per cent being gained by better working of the furnace during the second period.

Benefit of the Process in Eliminating Hydrogen. — L. Grabau gives figures which he claims show that the heat necessary to dissociate the aqueous vapor is only 2 per cent of the total heat produced, and would be of no practical importance, especially as the loss would be in part at least regained by the increased value of the furnace gases. He thinks, however, that the question of drying the blast may become of great importance if the following suppositions are correct. The decomposition of aqueous vapor is carried out by the agency of carbon, the oxygen immediately forming carbon monoxide, as there is no possibility of its uniting with the iron. With the hydrogen the case is different; a part passes through the furnace and reappears in the gas, but another part unites with the molten metal. Here it constitutes a dangerous impurity, and nothing which will limit its amount, such as drying the blast, should be neglected. Hydrogen is the principal cause of porosity in certain kinds of iron, and also in the steel, especially steel castings, for which it forms the raw material.

A Criticism of the Process. — A. Lindner of the Teplitz Iron Works draws attention to the fact that Mr. Gayley avoids any estimate of the decrease in costs to be effected by the use of his process. He thinks that the startling results obtained at the Isabella furnaces can be explained by investigating another source of heat, namely, the coal burned under the boilers, and is strengthened in this opinion by learning that such coal is obtainable in Pittsburg at 90 cents per ton. He attempts to calculate the amount of steam coal required when running with natural and dried blast, respectively, but admits that his results can only be approximate, on account of the meager data available. He figures the heating value of the gases with both methods of working, deducting in each case the amount of heat required in the stoves, the remainder being available for steam production. With natural blast this remainder must be considerably larger than with dried blast, and from the difference the increased steam coal necessary can be figured. The power required for the production of blast in the former and for the production of blast and for drying it in the latter case is about the same. For natural blast his calculation shows the amount of heat available

for steam making purposes per 100 kilos pig iron to be 294,062 calories, while with dried air the equivalent is 187,781 calories. These figures must be reduced to a similar time unit, as the daily production was different for the two methods. For one hour the figures for natural air are 44,992,098 calories and for dried air 35,490,609 calories, showing a difference of 9,501,489 calories per hour, or 50,273 calories per 100 kilos of metal. Assuming a coal of 7,000 calories heating value and a calorific efficiency of the gas firing of 0.8, the amount of steam coal required would be 8.20 kilos. The fuel consumption with dried blast would therefore be;

	Kilos
Coke	77.7
Coal	8.2
Total fuel	85.9

This result compares with 96.60 kilos of coke with natural air. The fuel saved is therefore only 10.7 kilos, equals 11 per cent, while the saving in coke is 19.5 per cent. In money the saving would be more than 11 per cent, owing to the difference in price between coke and coal.

It is apparent from the above that if the furnace gas is completely utilized for heating the blast and generating power, it is essential to determine the amount of heat passing out with the gas when comparing the cost of working in two different furnaces. The case may occur where it is economy to use more coke than necessary for the reduction of iron in order to enrich the gases.

Mr. Lindner disputes Professor Osann's assertion that a coke consumption as low as 77.7 kilos cannot be maintained, and publishes a "heat balance" in which he uses Mr. Gayley's gas analyses to determine the credit side or sources of heat, and Professor Osann's figures for the debit side, and which seems to bear out his contention. He contends, however, that an equally favorable result can be obtained with the blast in its natural state because the dissociation of the moisture in front of the tuyères does not entail any other loss than that carried up the draft stack by the water vapor in the form of sensible heat. This contention he bases on the fact that the heat necessary for dissociation is regained by the reunion of the hydrogen and

oxygen, either in the furnace itself, in the stoves or under the boilers, and does not directly cause any increased consumption of fuel. The heat thus lost up the stack is too insignificant in quantity to merit consideration. Indirectly, however, the loss is much greater, as by reason of the heat necessary for dissociation the pyrometric effect in the bosh is lowered, which decreases production and causes greater loss by radiation and conduction. This loss due to moisture in the air can, however, be even counteracted by raising the blast temperature, an increase of 94° C. being sufficient to take care of the moisture at Etna. This writer also contends that when working with moist air Mr. Gayley was using too much coke, which accounts for the much less favorable results obtained at Isabella than at Edgar Thomson in respect to production and coke consumption, the latter works under similar conditions using 82 per cent coke and making a greater tonnage.

Regarding the increased uniformity in composition of the pig iron attained by the use of dry air, on which Mr. Gayley lays great stress, Herr Lindner points out that the assertion is not substantiated by the publication of analyses, and he claims that this would be of less influence than variation in the iron contents and moisture of the ore. The decreased production of flue dust he ascribes not to the increased uniformity in the amount of moisture in the blast, but to the lower blast pressure and the greater weight of the furnace contents by reason of the decreased percentage of coke.

Mr. Lindner closes by an expression of his opinion that Mr. Gayley's work at the Isabella furnace is an experiment on a grand scale, which will probably not be repeated, and that an invention which has no other use than to counteract the effect of 69 pounds of water per ton of iron is not of the epoch-making importance claimed in some quarters.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

OPEN-HEARTH Furnaces. G. L. Luetscher. "Proceedings of Engineers Society of Western Pennsylvania," March, 1905. 6,000 w., illustrated. — The author describes various types and sizes of open-hearth furnaces. Besides the so-called stationary furnaces there are in operation quite a number of furnaces with revolving hearths. Such furnaces have the advantage that the steel can be poured out at any desired moment and in any desired quantity without the obnoxious operation of opening, cleaning and careful closing of the taphole. There are two distinct types of such tilting furnaces, — the Campbell type and the Wellman type. In the first one, the hearth, supported on rollers, revolves around its center line, coinciding with the center line through the ports. The gas and air connections are such that the gas does not have to be shut off in any position of the hearth. In the second one, the hearth is pulled out of the center line around a pivot under the hearth and outside the center line. When this furnace is tilted, the gas has to be shut off entirely.

Much has been said pro and con in the discussion of the merits of these tilting furnaces, the main objection being the high first cost, the difficulty of maintaining the roofs, etc., and the accessibility of cold air through the more or less defective joint between the stationary and movable parts.

The open-hearth furnaces, especially the ones with basic

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* Note. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

lining, are becoming more and more the main producers of steel, especially since the use of fluid pig metal taken from the blast furnace or mixer has been found practicable. The fuel commonly used is producer gas, in the Pittsburg district natural gas, and in some works petroleum, crude or semi-refined, or, even as in Russia and Austria, coal-oil residue. According to the quality of raw material to be melted and the quality of the finished steel desired, a good basic furnace of about 35-ton capacity should produce ingots with about 600 to 650 pounds of fair gas coal per gross ton of ingot. This figure can and has been materially improved upon. Acid furnaces, of course, should require less fuel, so will basic furnaces with a minimal lime charge melting clean, good, raw material and producing ordinary qualities of steel. However, there are many furnaces in operation which consume considerably larger amounts of coal. With natural gas, good practice shows a consumption of about 5,600 to 6,000 cubic feet per ton. With coal oil the figures obtainable vary considerably, though about 45 gallons per ton of steel ingots seems to represent a fair average. A good 25-ton basic furnace should make about 17 to 18 heats per week of six days, a 50-ton one about 14 to 15, with cold but fair raw materials.

Of late the use of fluid blast-furnace metal has brought about some special processes like the duplex process, a combination of acid Bessemer fining and basic open-hearth finishing work, and the Bertrand-Thiel process — carried out by a combination of a primary preliminary washing basic furnace and a secondary finishing furnace, also basic. The first mentioned process was advocated by me for the working of the irons of the Birmingham, Ala., district some fifteen years ago, and is now finally in successful use at the Ensley, Ala., Steel Works; and its application in this district may eventually prove to be successful, too, notwithstanding the adverse criticism of great authorities. The second process is so far not applied in the United States, but could be successful especially by the use of tilting furnaces and a ladle for transferring the partly purified metal from one furnace to the other. It is at present in use at the steel works in Hoesch, Germany, and Kladno, Austria.

The Monell process, partly in use in the different Carnegie plants, consists in charging in a basic open-hearth furnace, lime-

stone and a relatively large quantity of ore, heating these and then charging molten pig metal from a mixer or direct from the blast furnace. The temperature of the resulting mixture must be low enough to insure rapid oxidation of phosphorus. The slag formed rises and is drawn off at a cinder notch, taking with it practically all the phosphorus and silicon. Within an hour after charging the molten pig, the bath is free from phosphorus, silicon and manganese, and the bulk of the slag containing these impurities is removed while the carbon in the bath is still high. The heat is then finished as usual and finally tapped when the carbon has reached the desired point. The Monell process was the logical outcome of experiments made in 1898 for the use of large percentages of fluid pig metal. It is in use also in Donawitz, Austria, and in a Russian steel works.

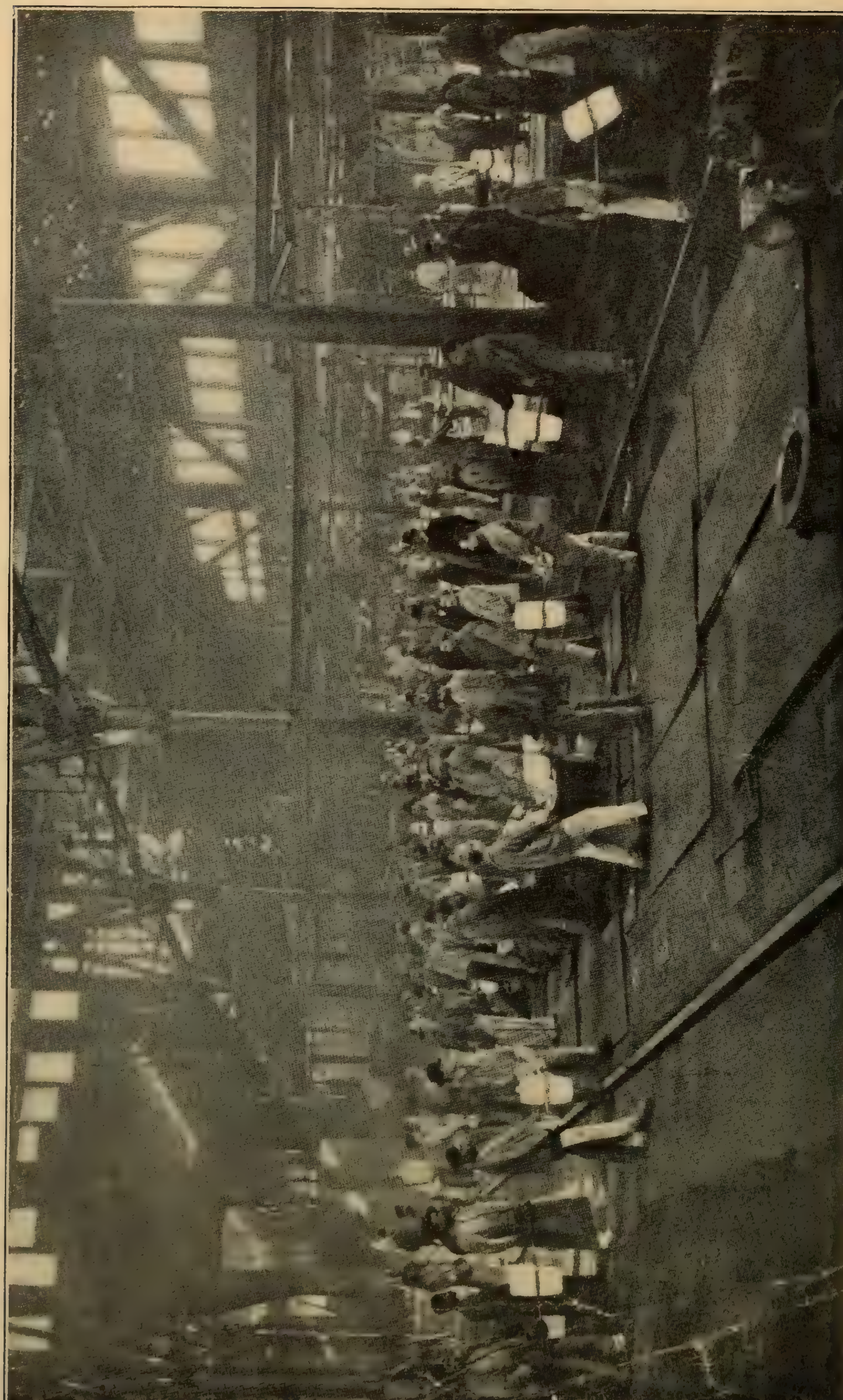
The Talbot continuous process requires the use of a basic-lined tilting furnace of large capacity (75 to 100 tons or more). The furnace is charged Sunday evening with about 50 per cent scrap and 50 per cent pig, and this first heat or filling is worked down to steel in the usual way. When the bath is good finished steel, about one third of it is poured off into a ladle and cast into ingots. No slag is run off with the steel. After tapping off this third of the charge, oxide of iron is added to the slag, and as soon as this is melted, about 20 tons of molten metal are run in to replace the steel tapped off. Immediately a violent reaction takes place, large volumes of CO gas are given off, which ignite and burn with intense flame, the heat of which partly raises the temperature of the bath and partly is absorbed by regenerators. After the reaction has ceased, *i. e.*, about 15 to 20 minutes, the slag, which is now almost deprived of iron oxide, is partly poured off and the bath is worked down into finished steel by fresh additions of iron ore and lime. When the bath is ready, one third or about 20 tons of steel is cast, fresh slag additions are made, and another 20 tons of molten pig metal added as before. These operations are continued during the whole of the week, the furnace being completely emptied only on Saturday. This process is in use in Frodingham and Cardiff, England, and at the Jones & Laughlin Steel Works in Pittsburg, who lately have added several more tilting furnaces for the making of steel by the Talbot process. A modification of the Talbot process is being applied at the B. Hantke Steel

Works in Czenstochau, Russia, by Surzicks, a stationary furnace being supplied with two tapholes, of which the upper one serves for letting out one third of the contents of the furnace, the lower one for the complete emptying. Perhaps the use of a third tap-hole, still higher up, for the removal of slag would be an improvement, and thus the Monell and Talbot processes could be combined. **No. 342. D.**

The Krupp Works. Emile Guarini. "Cassier's Magazine," April, 1905. 4,000 w., illustrated. — These famous works give employment to nearly 150,000 people, of whom 25,000 belong to the Essen branch of the establishment. The entire works are made up of eight different groups as follows:

1. The steel works at Essen, with the testing field of Meppen.
2. The steel works at Annen.
3. The Gruson Works at Buckau.
4. The Germania Dockyard at Kiel.
5. The four blast furnaces at Rheinhausen, Duisburg, Neuwied and Engers, and the steel works at Sayn.
6. The three coal mines of Hannover, Hannibal and Salzer and Neuack.
7. Numerous iron mines in Germany and a share in the Bilbao mines in Spain.
8. The Rotterdam Dockyards. **No. 343. B.**

Application of the Phase-Rule to Mixtures of Iron and Carbon. H. W. Bakhuis Roozeboom. "Zeitschr. Elektro-chem." 8,000 w. Paper read before the 11 Hauptversammil. der Deutsch. Bunsen Gesell., May 12–14, at Bonn. — The scheme described is in most respects similar to that put forward in 1900. The modifications introduced are three: (1) It is doubtful whether graphite or cementite is stable in contact with iron at high temperatures, and a dotted curve has been added to indicate the possible separation from the melt, of cementite in place of graphite. (2) Carpenter and Keeling have detected a liberation of heat at 800°, which may be due to the formation of a second modification of cementite. It is indicated in the diagram by a horizontal line running across the cementite area. (3) These investigators have also detected a change at 600°, which they attribute to a change in the iron. This change is indicated



The Essen Crucible Steel Foundry

by a horizontal line running across the pearlite area. It has been suggested that possibly cementite is metastable at all temperatures. Stable equilibrium would then only be possible between iron and graphite. If this be so, however, such an equilibrium would be reached only after very prolonged heating, as under normal conditions cementite is always produced. "Science Abstracts," February, 1905. **No. 344. C.**

Welding Broken Bosses on Rolls. "The Iron Trade Review," March 16, 1905. 1,500 w., illustrated. — The article describes the welding of broken bosses on rolls by the use of thermit, which does away with the necessity of heating the broken boss red hot. Thermit, ignited on a cold surface, deposits on it a layer of its corundum slag, which adheres firmly. To avoid this, a thin layer of cast iron or steel is poured on to the welding surface before thermit is placed on it, and to avoid the adhesion of corundum at the sides, a concentric iron ring is so fixed in the mold that it can be withdrawn after ignition of the thermit.

The main feature of this application of thermit, for which no crucible is required, is the advantage gained by being able to bring any surface to welding heat, and that in an even and speedy manner. **No. 345. A.**

Lifting Magnets for Handling Iron and Steel. "Machinery," March, 1905. 850 w., illustrated. — It is claimed that wherever iron or steel is handled in quantities by means of cranes, an electromagnet should effect economies in time and labor sufficient to pay for itself in from one to six months. This is borne out by the experience of the Illinois Steel Company, who use fourteen magnets in their South Chicago shops alone, where they have found the economy in time and labor so marked that they have decided to use them wherever possible throughout their works. These magnets have been found particularly useful in steel mills, jobbing houses, safe works, foundries and other places where iron or steel pieces have to be handled in large quantities, in which cases the labor cost of attendance is a considerable item.

The design of this type of magnet is the result of a series of experiments to obtain the most efficient design for the hand-

ling of iron and steel objects of irregular shapes in blocks. The lower end of the center pole is not in the same plane or level as the outer pole, but when the magnet is set down on the floor, for illustration, the center pole does not touch it within 2½ or 3 inches. In this way an intense magnetic field is obtained which concentrates the load around the center pole. The lifting magnet, shown in Figs. 1, 2 and 3, weighs from 1,500 to 1,700 pounds, equipped complete with chains for attaching it to the crane. **No. 346. B.**

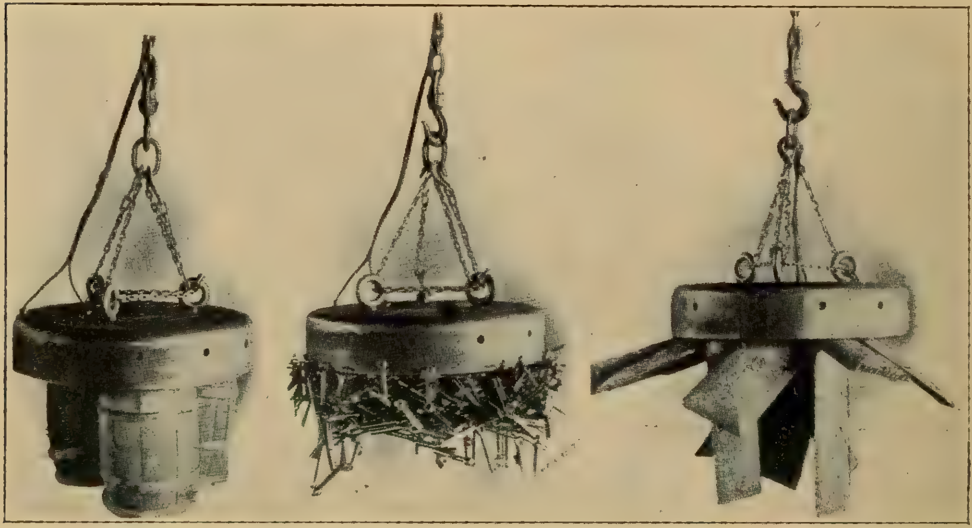


FIG. 1. Magnet Lifting Three Kegs of Cotters; Heads on Kegs
FIG. 2. Magnet Lifting Contents of Three Kegs, in Loose Form
FIG. 3. Magnet Lifting Twelve Pigs of Pig Iron Weighing 900 Pounds

Equipment and Work of Metallographical Laboratories in Germany. E. P. Buffet. "American Machinist," March 16, 1905. 2,500 w., illustrated. — The author describes the equipment of metallographical laboratories recently installed at the Royal Material Testing Laboratories at Gross-Lichterfelde West, connected with the Berlin Technical High School, and at the Ironmakers' Institute of the Royal Technical High School at Aix-la-Chapelle. **No. 347. A.**

Commercial Possibilities of Blast-Furnace Gas for the Development of Electric Power. F. du P. Thomson. "Electro-chemical and Metallurgical Industry," March, 1905. 6,000 w. — An authoritative and able review of an important and timely

question. The author concludes as follows: "Wherever there is a large demand for power and cheap water power is not available and blast furnaces are, the blast furnace gas-engine power plant need fear no rival. We are not far from the day when the power house will be as much a part of every modern blast-furnace plant as are the condenser and ammonia houses of the modern by-product coke plant." **No. 348. B.**

Blast-Furnace Gas Engines at the Ilseder Iron Works. E. Guarini. "Power," March, 1905. 800 w., illustrated. — The author describes and illustrates an Oechelhæuser gas engine installed at the new power plant of the Ilseder Iron Works, in Northern Germany. **No. 349. B.**

The Use of Waste Gases in Large Gas Engines. Max Rotter. "The Iron Age," March 16, 1905. 3,500 w. — Paper read before the Illinois Steel Works, Scientific Club, Joliet, Ill., March 1, 1905. The author discusses the direct use of waste gases from coke ovens and blast furnaces in large gas engines. **No. 350. B.**

The Melting and Cooling of Foundry Iron. "American Machinist," March 30, 1905. 2,000 w. — Abstract of a recent address by R. Buchanan before the Coventry (England) Engineering Society. **No. 351. A.**

Chemistry in Foundry Practice. N. W. Shed. "The Iron Trade Review," March 2, 1905. 2,000 w. — Paper read at a meeting of the Buffalo Foundrymen's Association, February 21, 1905. **No. 352. A.**

Pig Irons and their Use in the Foundry and Forge. E. Adamson. "The Iron and Coal Trades Review," March, 1905. 3,200 w. — Abstract of a paper read before the Manchester (England) Association of Engineers. The author describes English pig irons and considers their typical analysis, quality, grading, etc. **No. 353. B.**

The Frodingham Iron and Steel Company's New Electrical Plant. "The Iron and Coal Trades Review," March 3, 1905.

3,000 w., illustrated. — A description of a power and lighting plant installed by the British Westinghouse Company. **No. 354. B.**

Iron Ore Movement in the United States. John Birkinbine. "The Iron Trade Review," March 16, 1905. 1,200 w. — Extract from a paper read before Section D, Mechanical Science and Engineering, at the Philadelphia meeting of the American Association for the Advancement of Science. **No. 355. A.**

New Open-Hearth Furnaces, Blooming Mill and Structural Steel Plant of the Illinois Steel Company. "The Iron Trade Review," March 2, 1905. 9,000 w., illustrated. **No. 356. A.**

A New Testing Machine for Reversals of Stress. J. H. Smith. "Engineering," March 10, 1905. 1,500 w., illustrated. —Description of a reversal testing machine constructed for the Sunderland Technical College. **No. 357. B.**

Alternating Stress Testing Machine at the National Physical Laboratory. T. E. Stanton. "Engineering," February 17, 1905. 4,500 w., illustrated. **No. 358. B.**

Ueber den Einfluss von Kohlenstoff, Phosphor, Mangan und Schwefel auf die Bruchfestigkeit des Martinstahls. (The influence of Carbon, Phosphorus, Manganese and Sulphur upon the strength of Open-Hearth Steel.) "Stahl und Eisen," January 15, 1905. 4,200 w. — The author discusses H. H. Campbell's formula for determining the strength of steel from its composition. **No. 359. D.**

Magnetische Eigenschaften des Gusseisens. (The Magnetic properties of Cast Iron.) H. Nathusius. "Stahl und Eisen," January 15, 1905. 2,500 w. — The author discusses the relation between the chemical composition of cast iron and some of its magnetic properties. **No. 360. D.**

The Uses of High Speed Steel. G. H. B. "Machinery," April, 1905. 2,500 w. **No. 361. B.**

METALLURGICAL NOTES AND COMMENTS

David Baker The well-known metallurgist and engineer, David Baker, a recent photograph of whom is reproduced as a frontispiece in the present issue, was born in Boston, Mass., in 1861. He acquired his technical education at the Massachusetts Institute of Technology, from which he graduated in 1885. Immediately after his graduation he secured employment in the Bessemer department of the Pennsylvania Steel Company at Steelton, Pa. His rise was exceptionally rapid, for in the early part of the next year he was appointed assistant superintendent of the blast furnaces and the following year promoted to the superintendency of that department. In 1887, Mr. Baker was placed in charge of the construction work of the Maryland extension of the Pennsylvania Steel Company, at Sparrows Point, Md., assuming, after their completion, the practical operation of the blast furnaces.

In 1894 and 1895, during the shutdown of the manufacturing departments of the Maryland Steel Company, Mr. Baker was in charge of the Lackawanna Iron and Steel Company's blast furnaces at Lebanon and Cornwall, Pa., but upon the resumption of work at Sparrows Point, he returned to that place to again take charge of the blast furnaces, and shortly afterwards was appointed metallurgical superintendent of that plant.

From 1898 to 1901, Mr. Baker was in charge of the blast furnaces of the Illinois Steel Company, at South Chicago, Ill., and in the latter year accepted the general superintendency of the Dominion Iron and Steel Company, being shortly afterwards appointed general manager at those works. In 1904, he resigned this position and since then has been engaged in consulting engineering work as associate to James B. Ladd, consulting mechanical engineer.

A better and more successful training than that of Mr. Baker could hardly be conceived, and he is, without doubt, one of the very best blast-furnace experts living. In his consulting

work he gives special attention to coal washing, the design and operation of blast furnaces as well as the design of Bessemer and open-hearth steel works and steel castings plants.

Mr. Baker has written many technical papers, chiefly on blast-furnace practice and blast-furnace equipment, most of which are to be found in the transactions of the American Institute of Mining Engineers.

New Blast Furnace and Steel Works Records

The favorable weather which prevailed during March, the fact that this 31-day month contained only four Saturdays and four Sundays, and the enormous demand for iron and steel have contributed to the making of many new records for production. Of course many achievements of this sort do not come to light, but the summary made below is sufficient to indicate that American works have been doing very well indeed.

Pig-Iron Production. — The admirable monthly summary of "The Iron Age" shows that during the month of March there were produced 1,936,229 gross tons of coke and anthracite pig iron, against the best previous month's record of 1,781,847 tons, in January, 1905, and the next best of 1,713,614 tons, in May, 1903. Estimating charcoal pig-iron production at 33,771 tons, the total pig-iron production in March would be 1,970,000 tons, or at the annual rate of about 23,200,000 tons. This record was achieved not alone through the large number of furnaces in blast, but also through heavy production at individual furnaces. The furnaces, as a whole, probably did better, relative to their normal capacity, than ever before.

Edgar Thomson Furnaces. — Furnaces D, E, J and K of the eleven furnaces in the Edgar Thomson group at Bessemer, Pa., in March, broke the world's record for four blast furnaces by making 77,242 gross tons. The record had been previously held by the four Duquesne furnaces, which, in October, 1904, made 74,605 tons. Before this it had sometimes been necessary to select furnaces from three different plants to reach the maximum total for four furnaces. The March record is made up as follows: D, 17,982 tons; E, 17,745 tons; J, 20,244 tons; K, 21,271 tons; total, 77,242 tons. The world's record for a day's output of one furnace was made by K on March 30, with 918 tons.

Clairton Steel Plant. — In March the Clairton basic open-hearth steel plant of twelve 50-ton furnaces broke the world's record for a plant of its size by making 42,387 gross tons of ingots. The performance is the more creditable from the fact that the average scrap consumption was only 28 per cent. The iron came from the Clairton furnaces through the mixer, and ran about 0.5 per cent phosphorus and under 1.0 per cent silicon. The average time of heats was a trifle over 8 hours.

Ensley Steel Plant. — The steel plant at Ensley, Ala., of the Tennessee Coal, Iron & Railroad Company, broke its own record in March. It contains ten 50-ton basic open-hearth furnaces, with an auxiliary primary furnace or mixer and a Bessemer vessel, for partially desiliconizing and decarburizing. Scarcely any scrap is used. The output was as follows: Ingots, 23,003 tons; blooms and slabs, 19,923 tons; rails, 16,244 tons. In one day 1,020 tons of ingots were cast.

Homestead Steel Works. — In March, No. 3 open-hearth plant, containing twenty-four 45-ton furnaces, made 80,000 tons of ingots; Nos. 1 and 2, containing three, twenty and twenty-three 40-ton furnaces, made 70,000 tons. The Bessemer department, containing two 10-ton vessels, made 40,000 tons. The total, 190,000 tons of ingots, breaks the plant's record. The record number of heats per week had been 14 at this plant, but at several furnaces 16 were made in a week during March. The large blooming mill at the plant made 63,400 gross tons of billets, a world's record.

Illinois Records. — The South Works of the Illinois Steel Company, containing three 15-ton converters, produced 86,900 tons of ingots in March, breaking the plant's record by 3,759 tons. The Joliet plant, containing two 10-ton converters, produced 57,672 tons, breaking its record by 3,570 tons. This plant's 24-hour record was also broken, with an output of 2,541 tons.

Shenango Steel Works. — The Shenango steel works at Newcastle, Pa., owned by the Carnegie Steel Company, but originally built by the Shenango Valley Steel Company, contain two 10-ton converters, a 36-inch blooming mill and a tandem billet and sheet bar mill, of nine stands of billet and nine stands of sheet bar rolls, driven by four engines, connected partly

direct and partly by rope drives. In March the output was 56,262 tons of ingots and 50,055 tons of billets and sheet bars, the best day's record on the latter being 2,346 tons.

A Morgan Continuous Mill. — The Morgan continuous mill at the South Chicago, Ill., plant of the International Harvester Company receives 4 x 4 billets to be rolled to 7-16 to 2-inch rounds, $\frac{3}{8}$- to $1\frac{3}{4}$-inch squares, etc., and contains a continuous roughing mill of eight stands, a finishing mill of four stands and a bull head of two stands. It made a new record in March with 7,540 tons in the 54 turns.

Tin Mill Record. — What is undoubtedly a world's tin mill record was made during March by the McKeesport Tin Plate Company, McKeesport, Pa. The plant contains ten single-stand tin mills, and produced during March 2,671.63 gross tons of black plate. Tin mills are customarily operated sixteen 8-hour turns per week, and the plant operated steadily, thus running 730 turns for the ten mills. The average output per turn was 8,197 pounds, the average gauge being 30.51. The mill is operated non-union. The output limit of the Amalgamated Association is 6,250 pounds on 30 gauge and 6,050 pounds on 31 gauge, but these limits are not always adhered to at the union mills. Turns below the limit are not allowed to be made up, so that a month's run at the average of the output limit would not be an uncreditable performance. The McKeesport plant made an average of just one third beyond the limit.

American Sheet and Tin Plate Company. — During March this company broke its records in shipments of both tin plates and sheets. The shipments of " tin mill products," chiefly tin plate, but including some black plate, etc., were 54,924 gross tons, and of sheet mill produces 54,392 gross tons. The company has 242 tin mills and 163 sheet mills. These mills were operated steadily except for occasional breakages, etc. The shipments substantially represent current output.

The Steady Increase in Open-Hearth Steel. — The march of the basic process for the manufacture of open-hearth steel in the United States is probably the subject of more frequent comment than any other single development in the iron industry. But the statistics for 1904 giving the production of Bessemer and open-hearth steel present more sharply than those for any

other year the contrast between the records of the converter and the open-hearth furnace. They show that while the production of Bessemer steel ingots declined 733,689 tons, or from 8,592,829 tons in 1903 to 7,859,140 tons in 1904, the output of open-hearth steel increased by 77,755 tons, or from 5,829,911 tons in 1903 to 5,907,666 tons in 1904. This latter increase was due to the expansion in the basic open-hearth steel industry which amounted to no less than 371,454 tons in the year, enough to more than offset the decline of 293,699 tons in the output of acid open-hearth steel.

It is significant that no column of figures, representing production of any description of iron or steel in the United States over a series of years shows the unbroken record of increase, year after year, that is exhibited by the statement of output of open-hearth steel ingots and castings. Pig iron and Bessemer steel have their ups and downs — their periods of expanding production, followed at intervals by a falling off, so that the output in a particular year will be lower than in the year preceding. The same is true of rails and of the various other forms of finished material. The advance to new records of output is not a regular nor is it an uninterrupted progress. We have brought together the figures in the table below for the purpose of emphasizing the exception in the case of open-hearth steel — and this characteristic of the open-hearth steel figures, it should be noted, is due almost entirely to the rapid extension of the basic process. The third column in the table gives the production of basic open-hearth steel in the years for which separate statistics for the basic product were gathered by the American Iron and Steel Association. The estimate for 1890 is taken from the report of the association for that year:

PRODUCTION OF STEEL IN THE UNITED STATES — GROSS TONS

	Bessemer Steel	Open-Hearth Steel	Basic O. H. Steel
1890	3,688,871	513,232	Est. 80,000
1891	3,247,417	579,753	....
1892	4,168,435	669,889	....
1893	3,215,686	737,890	....
1894	3,571,313	784,936	....
1895	4,909,128	1,137,182	....
1896	3,919,906	1,298,700	776,256
1897	5,475,315	1,608,671	1,056,043

	Bessemer Steel	Open-Hearth Steel	Basic O. H. Steel
1898..........	6,609,017	2,230,292	1,569,412
1899..........	7,586,354	2,947,316	2,080,426
1900..........	6,684,770	3,398,135	2,545,091
1901..........	8,713,302	4,656,309	3,618,993
1902..........	9,138,363	5,687,729	4,496,533
1903..........	8,592,829	5,829,911	4,734,913
1904..........	7,859,140	5,907,666	5,106,367

Panics, depressions, labor troubles, short crops and all the vicissitudes they have brought into the iron trade, have been promptly reflected in Bessemer steel as they have in the pig-iron industry; but none of these things has once interrupted the onward march of basic open-hearth steel. Its record is in this respect unparalleled in the annals of the world's iron trade.

Not only is it true that open-hearth steel has enlarged its place in the lines in which it has furnished the bulk of the tonnage for a number of years, — plates, structural shapes, steel castings and forgings, — but it is now contributing an increasing share of the output of rails, bars, sheets, tin plates and wire products. This may be considered a virtual displacement of Bessemer steel, since all these products, with the exception of bars, have until very recent years been the peculiar field of the Bessemer converter.

It should be noticed in the table above that, whereas Bessemer steel fell off nearly 1,300,000 tons from 1902 to 1904, basic open-hearth steel in the same interval increased 610,000 tons. From being 12 per cent of the total of Bessemer and open-hearth steel in 1890, the open-hearth product had come up to 34 per cent in 1900, 35 per cent in 1901, 38 per cent in 1902, 40 per cent in 1903 and 43 per cent in 1904. It is noteworthy also that the decline of 546,000 tons in Bessemer steel ingot production in 1903, as compared with 1902, was not due to a cutting down of the Bessemer steel rail output, the latter having been even slightly greater in 1903 than in 1902, — 2,946,756 tons, as against 2,935,392 tons.

The increase in open-hearth steel production last year over 1903 was in spite of a decline in the output of steel foundries. As shown in the statistics printed elsewhere in this issue, the output of open-hearth steel castings in 1904 fell off from 400,348 tons to 302,334 tons, or about 25 per cent.

On the question of scrap supply for open-hearth steel manufacture the figures give some information that is interesting. As has been pointed out heretofore in these columns, pig metal is entering more largely in the past few years into basic open-hearth mixtures — due, in the case of some of the smaller plants, to the increasing scarcity of scrap, and, at the larger works, to the taking of direct metal from furnaces and the increased use of processes employing all or nearly all pig iron. In 1896, the first year for which basic open-hearth steel statistics were gathered, the production of basic pig iron was 43 per cent of the production of basic steel; in 1900, it was 42 per cent; in 1901, it was 40 per cent; in 1902, it had jumped to 45 per cent, and last year it was 48.6 per cent.

A steadily increasing use of non-Bessemer ores, both actually and proportionately, is pointed to by the last three lines in the statistical table given above, as well as by the known developments in construction of Bessemer and open-hearth plants and the market demand for Bessemer and open-hearth material. "The Iron Trade Review," March 16, 1905.

Raw Materials for Basic Open-Hearth Steel. — A very interesting development has been going forward in the basic open-hearth steel industry. It will be recalled that the first commercially important adoption of this process in the United States was about a decade ago, while in the preceding decade the process had undergone extensive adoption abroad, with many changes in the details of practice.

The question of a scrap supply has been the most inportant element governing the evolution of the basic open-hearth steel industry in the United States. This is but natural considering that, in 1896, the first year for which separate statistics were returned, there were produced in the United States only 776,256 gross tons of basic open-hearth steel ingots, while eight years later, in 1904, the production as just returned was 5,106,367 tons, or more than six times as great. In the early days this process was regarded with favor, largely, because it offered a ready means of utilizing scrap, which was then cheap, while by its rapid expansion it has now made scrap dear, to such an extent that a number of sales of heavy melting scrap have been made within the past few months at a somewhat higher price,

delivered, than that for which basic pig iron could be purchased. Almost as soon as this process for utilizing scrap became well founded, the engineers began to cast about for means to avoid the use of this very material, from which have come the Talbot, Monell and accessory converter processes.

It has long been recognized in self-contained steel works in the United States, with blast furnaces and Bessemer converters, that the blast furnace is entirely the servant of the steel works, that it has no rights of its own. With the basic open-hearth steel process this principle was not recognized so early, largely from the incident that a greater percentage of basic open-hearth steel is made from purchased pig iron than is the case with Bessemer steel. The furnace manager is less disposed to submit to the dictation of a chance customer than to the dictation of a common owner of both steel works and blast furnace. Gradually this has been changing. The steel works manager knows better than formerly what he wants in his pig iron, and the furnace is more disposed to give it to him. With the increasing relative price for scrap the steel works is willing to pay a slightly better figure for the pig iron, which is, of course, an inducement. A few years ago basic pig iron ruled pretty regularly at a dollar or so a ton below Bessemer pig; of late the two have been selling at almost, if not exactly, the same figure. Until a comparatively recent time the recognized contract specification for phosphorus was a limit of 1 per cent, although at no time was there a great deal of northern iron made approaching this limit. Lately it has been possible to have written in the contract a limit of 0.50 per cent on northern iron, while with some producers it is possible to obtain a guarantee of not over 0.30 per cent in phosphorus, the iron actually running, say, from 0.20 to 0.25 per cent. The importance of phosphorus in fixing the value of basic pig iron appears, however, to have been overrated in some quarters, which is indicated by the following incident: A steel works which had been using a basic pig running under 0.50 in phosphorus was solicited to buy a totally different variety, averaging about 1 per cent, and, objection being raised, the seller offered to ship 200 tons and accept a check for whatever the steel works considered the iron actually worth, provided it would carefully study the results obtained. The outcome was a voluntary settlement at only

30 cents per ton under the recognized price for the iron running more than ½ per cent less in phosphorus. This small difference is not claimed to have proved that phosphorus in itself is of such little importance, because the higher phosphorus iron ran only about 0.40 per cent in silicon. Rather it points to the importance of silicon.

When the statistics of pig-iron production in 1904 by grades appeared, it was rather noteworthy that, although the total production showed a decline of 1,512,219 tons from 1903, the production of basic pig (made with mineral fuel) showed an increase of 442,378 tons, the decrease in all grades other than basic being 1,954,597 tons. This increase in basic pig production was not due entirely to the increase in basic open-hearth steel manufacture, since the increase in the latter was only 371,454 tons. A greater proportion of pig iron and a smaller proportion of scrap was used in 1904. Comparisons such as this are only rough, but they are indicative. In 1903, the tonnage of basic pig produced was 43.1 per cent of the tonnage of basic open-hearth steel ingots. In 1904, the percentage rose to 48.6 per cent. This percentage has varied somewhat irregularly. In 1896, it was 43.3 per cent; the following year it rose to its maximum, 52.7 per cent; the minimum was 1901, with 40.0 per cent. It is quite possible that the low percentage shown in that year was an accident, since it is well known that at one time considerable quantities of substantially Bessemer iron were used, rather as an experiment, in making basic open-hearth steel, and it is not known just how this iron was returned for the statistics. The practice did not become fixed, as a little higher phosphorus, with lower silicon than in standard Bessemer, naturally gives better results.

Many forecasts have been made as to the future supply of scrap. It is an inviting field because it has few limitations but those of the imagination. Some points, however, appear obvious. As basic open-hearth steel production has increased much more rapidly than total steel production, the demands of the industry are certainly becoming harder to meet. In eight years basic production has increased from almost nothing to 5,000,000 tons; from a record production of a trifle under 5,000,000 tons nine years ago, Bessemer ingot production touched 9,000,000 tons in 1902, but declined to less than 8,000,000 tons last year.

In nine years the total pig-iron production has scarcely doubled. Again, it certainly seems that a smaller proportion of the total pig iron of the country is being converted into good scrap producing irons. Rails, the great scrap producer, constitute a less and less proportion of the total output. Many years used to be shown in which the tonnage of rails exceeded one fourth the tonnage of pig iron. On the other hand, an increasingly large proportion of the total pig iron is being converted into such light lines as wire, sheets, tin plates, hoops and bands, etc., obviously poor scrap producers.

It would appear that in the future the scrap used in the basic open-hearth steel industry will be a decreasing quantity, more and more confined to the new material, crop ends, shearings, etc., which can always be counted upon, while the demand upon the blast furnace for pig iron of an analysis contributing to economy of conversion into steel will be more and more exacting. "The Iron Age," March 16, 1905.

Finishing Open-Hearth Heats. — Carl Stobrawa writes on the above subject in "Stahl und Eisen" as follows:

Owing to the introduction of the Talbot process and variations of the same it has become a question of importance whether there is any difference in quality between steel finished in the ladle and that finished in the furnace. Experience undoubtedly points to the conclusion that there is, indeed, a great difference in favor of the latter method, and the purpose of these lines is to explain the reason.

In working a heat the carbon in the bath is oxidized by the oxygen in the ore, the air and the metal itself. When decarbonization has reached the point desired the excess of oxygen is removed by ferromanganese. In what form is the oxygen present in the bath? The answer is: In the form of ferrous oxide dissolved in the metal, which acts as a solvent in a manner similar to that of water in a solution of salt. When metallic manganese is added the following reaction takes place:

$$nFeO + Mn = MnOn + nFe.$$

The degree of oxidation of the manganese is higher than that of the iron — that is to say, the manganese compound is specifically lighter, rises to the top and goes into the slag; it may also be supposed that the solubility of the manganese compound

in the metal is less than that of the iron compound. This reaction takes place the more readily the hotter the bath, or, as the melter would put it, the sharper the furnace runs the better the steel. For the most complete separation possible of the ferrous oxide time is necessary, generally from 5 to 12 minutes. These two essential conditions, temperature and time, are absent when the heat is finished in the ladle, apart from the fact that in the latter case a homogeneous mixture of the materials added with the steel cannot be attained in the same degree as in a hot open-hearth furnace under a proper covering of slag. In order to aid the separation of the oxides the heat is sometimes allowed to stand a short time in the ladle before being poured. The covering slag also has considerable influence on the quality of the material. If it is too heavy or too sticky some of the alloys added cannot pass through the same, and their action on the metal is either retarded or prevented altogether. If the ferromanganese, for instance, does not melt until the heat is partly tapped it may result in the last part of the metal being higher in carbon and manganese than the first, causing lack of homogeneity. This is most likely to occur when pig iron is used without scrap and the metal is worked and finished in the same furnace. This method of working entails a comparatively thick covering of slag unless especially favorable conditions exist, such as iron low in silicon and phosphorus and a rich ore low in silica. If shortly before the ferromanganese is introduced the roof should get too hot, a condition favored by a heavy slag body, and if the supply of air is diminished in order to lower the temperature, the slag will become sticky and may easily prevent some of the alloy passing into the metal whereby the certainty of a first-class product is endangered.

Finishing heats in the furnace, as was formerly general, led to an almost perfect certainty in results, and for this reason it is to be recommended that the process of using direct metal in the basic furnace be so arranged that this method can be retained. The newest developments in the use of molten metal consist of treating the same with oxidizing substances in a separate furnace, according to the Bertrand-Thiel process, or with an externally fired mixer and stationary open-hearth furnace. In both cases the heat is finished in the furnace. Which of the two processes is the cheaper cannot be stated with any cer-

tainty. It may be pointed out, however, that in the fired mixer the removal of slag, which is a hindrance to the refining process, can be undertaken at any time. This is a point which is of considerable importance when using stock which yields much slag. Such a mixture makes the work more independent of any particular class of raw material. There is another question of far-reaching economic importance, especially for open-hearth plants where molten metal is not available and which are chiefly dependent on bought scrap, that is, whether firms which operate both blast furnaces and steel works will be able to cheapen the scrap process. And it must most probably be answered in the affirmative. If the scrap is spread evenly over the hearth with the limestone, and the partly refined metal is poured over the same after it has become thoroughly heated, melting will be much hastened and the whole process shortened.

We are only now witnessing the real introduction of the iron and ore process, and it is by no means improbable that further improvements will be made which will decrease the cost of the preliminary refining and render available for acid furnaces, such as are used in steel foundries, a suitable molten metal. "The Iron Age," March 9, 1905.

Manganese Steel Rails on the Boston Elevated. — Shortly after the Boston Elevated was opened to service, an alarming rate of rail wear was noticed at many places on the line. Heavy wear was anticipated on account of the numerous sharp curves and steep grades, but the actual length of service of the rails laid was much shorter than any previous experience on other steam or electric roads would have seemed to indicate. The original rails were commercial Bessemer steel, low in carbon or other hardening ingredients, and at some of the sharper curves they were completely worn out in from 40 to 50 days. There were a number of reasons for this rapid rate of wear; the curves were sharper than on any other road in the country; the grades were heavy and frequent and every car in the train is a motor car which intensifies the grinding effect on the top of the rail head because each pair of wheels become driving wheels, and if the train is stalled they will grind holes in the rails.

It was noticed at a number of the places where the worst wear took place that some of the rails did not wear as fast as

others, and this led to a careful analysis of the metal in the slow and rapid wearing rails. It was found that the slow wearing rails, though intended to be of the same composition as the soft rails, were higher in carbon and therefore had more surface hardness. A number of rails were rolled which were high in carbon, and these were laid in the track with uniformly good results, although on account of the extremely severe conditions of service, they still wore out with great rapidity. They lasted about three times as long as the ordinary commercial rails and cost but little more. Some nickel steel rails were also tried, and

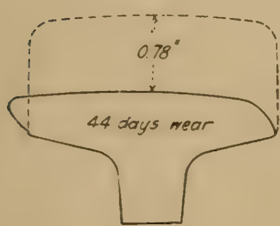


Fig. 1.

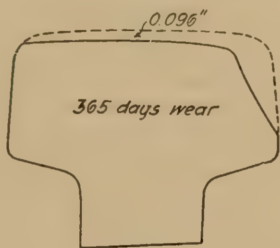


Fig. 2.

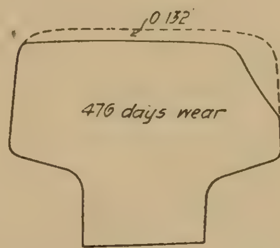


Fig. 3.

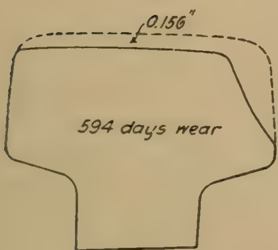


Fig. 4.

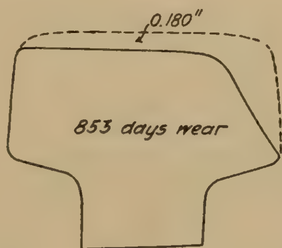


Fig. 5

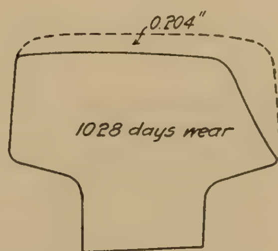


Fig. 6.

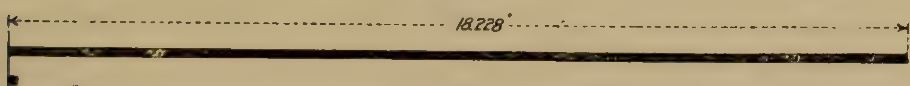


Fig. 7.

while they were an improvement over the commercial soft rails they did not prove in the end to have as long a life as the hard carbon steel rails. A nickel steel rail was laid on the outside of the 100-foot radius curve at Causeway and Haverhill streets between two hard steel rails, and measurements were taken at intervals of four weeks until the rails were taken up at the end of 204 days on account of the marked difference of wear between the nickel rail and the hard steel rails on either side of it. The nickel rail wore down on the head .528 inch in that time as against .18 inch for the hard steel rails, and the side wear was about in the same proportion.

Some time before this experiment was being made the southbound track at the entrance to the Park Street station in the Boston subway was laid with manganese steel rails supplied by William Wharton, Jr., & Co., of Philadelphia. This is on a reverse curve with a radius of 82 feet, or about 75 degrees, and the daily traffic passing this point is 44,000 tons a day. The commercial Bessemer rails first laid here wore out in 44 days or less, the amount worn off of the top in that time being .78 inch. Fig. 1 shows a section of the soft rail after being removed at the end of 44 days. The peculiar direction in which the head wore is at once noticeable. On the inside edge there is evidence of some side wear, but the top has worn down uniformly and is crowned almost the same amount as the original section. Only a slight burr is formed on the outside edge, showing that the top of the rail has been ground away and not squeezed out of shape. Figs. 2 to 6 show sections of the manganese rails laid at the same point on April 26, 1902. At the end of the first year the top wear was .096 inch and at the end of 1,028 days, on Feb. 17, 1905, the top wear was only .204 inch, and was uniform across the top of the rail head. It will be noticed that the side wear in the case of the manganese rail is rapid and uniformly progressive. Fig. 7 shows the comparative wear of ordinary steel and manganese steel rails for 1,028 days on the basis of the observed wear of each. It is too convincing to need comment.

At the present time the Boston Elevated has in its track about 475 feet of manganese steel rail, several ordinary frogs and three sets of crossing frogs made from the same material. The average life of the frogs and switches on curves is about four to six months, but on tangents the life is as long as that of the rails. When the manganese rails were first laid on the Park Street curve they were allowed to take all of the side wear, but they are now protected by a guard rail along the inside rail, which is greased several times a day, and which is allowed to take up the flange pressure. The grease prevents an undue wear on the guard rail. In the matter of cost the manganese rail is very expensive as compared to commercial Bessemer rail, but its long life makes it economical to use in such places as the elevated curves where rail renewals are expensive to make. The

manganese rail costs about $5 per foot as against 38 cents for Bessemer rail.

Manganese steel was first discovered about twenty years ago by Mr. R. A. Hadfield, the famous steel maker and metallurgist of Sheffield, England. In experimenting with various alloys of steel he found that an alloy of manganese and steel containing not less than 6 per cent and not more than 20 per cent of manganese possessed the remarkable property, that while already very hard when cast, if it is heated to a high temperature and suddenly cooled by plunging into water it becomes tougher and more ductile without losing any of its hardness, a phenomenon which is the exact opposite of that which is observed with any of the other hard carbon steels or steel alloys. The combination of hardness and toughness produces its great wearing qualities. Mr. Hadfield's first patents covered the alloy with the percentage of manganese stated, and the rights for making the alloy in the United States were secured by the Taylor Iron and Steel Company, Highbridge, N. J. Wm. Wharton, Jr., & Co., of Philadelphia, first made use of manganese steel in frog and switch work in this country. They have used it in special track construction for a number of years with excellent results, one frog made for the Pennsylvania having outlasted 17 frogs made of carbon steel. It has been used for guard rails on steam railroads, and a test is being made with split switches having manganese steel points.

Manganese steel is cast into the required shapes, as it cannot be rolled or machined. It is a metal exceedingly difficult to handle in the foundry, as it must be poured at a very high heat, and its shrinkage is enormous compared with ordinary cast steel. It is almost impossible to make intricate castings on this account, and the metal is so tough and hard that it cannot be machined. All finishing must be done with grinding machines. The rails furnished to the Boston Elevated were cast in 20-foot lengths with the bolt holes for the joint scored in the web. A drill which will drill a hole in a Bessemer rail three eighths of an inch deep in one minute makes no impression on a manganese rail. The rails are very ductile, however, as is shown by the following test of one of the 20-foot lengths. It was first bent cold to a 20-foot radius; half of the length was then straightened and bent to the reverse curve of 20-foot radius. The other end was then

bent to a 10-foot radius and no signs of fracture were observed at any point.

We are indebted to Mr. H. M. Steward, roadmaster of the Elevated Division of the Boston Elevated Railway, and to Mr. Victor Angerer, vice-president and general manager of Wm. Wharton, Jr., & Co., for the diagrams and information. "The Railroad Gazette," March 17, 1905.

Manganese Steel Rails. — The trials of manganese steel rails on the Boston Elevated, which are reported elsewhere in this issue, present a very remarkable case of rail wear on curves, not only in amount but in character. At the Park Street station, where the tests were made, the degree of curvature and the traffic passing over the rails are probably greater than on any other steam or heavy electric railroad, and for this reason the results are not directly comparable with the usual observed data of rail wear on steam roads. There are a few curves in use on steam roads having a smaller radius than 82 feet, but they are in yards or industrial switches which are only used at infrequent intervals, whereas the Boston Elevated carries a traffic of 44,000 tons a day. In the New York subway the maximum curve is of 147 feet radius, and on the Manhattan Elevated, the sharpest curve is of 90-foot radius, but no such remarkable wear has been observed there. The only feasible explanation for the amount of wear which takes place on the Boston Elevated is the fact that every car in the trains is a motor car, on account of the sharp curves and heavy grades, and that the wear of rails on the curves varies almost directly as the number of driving wheels passing around the curve. The flange wear seems to be no more rapid than might be expected, and the slow rate of speed at which the trains must round such a sharp curve excludes an assumption of excessive loading on the outer rail. In fact, the amount of wear on the outer rail would seem to indicate an excess of pressure on the inside rail and a consequent slipping of the wheels on the outer rail. Some time ago mention was made of the trouble experienced on this road with flat tires, and it may well be that the natural slipping of the outer wheel in addition to the slipping caused by the motors when working at full torque to overcome the curve resistance, causes the flat spots to grind the head of the rail much faster than if the wheel treads were per-

fectly smooth. The proportion of flange wear and top wear on the rails is unusual, particularly so in the case of the manganese rails. On curves of much larger radius on steam roads, the flange wear is much more pronounced, due to the longer rigid wheel base of the engines and the lack of side play in the couplings between cars. On the Elevated the rigid wheel base of the tracks is only about 6 feet, and the cars have radial drawbars, so that the flange pressure is much less than on an equivalent curve in steam road practice. However true this may be, it does not explain the lack of resistance to flange wear shown by the manganese rails, which are so superior to Bessemer steel rails in resisting top wear. This is an interesting metallurgical problem for which no solution has yet been advanced. "The Railroad Gazette," March 17, 1905.

Report of the United States Steel Corporation. — The third annual report of the United States Steel Corporation, for the fiscal year ended December 31, 1904, was made public on March 16. The total net earnings of all the properties, after deducting expenditures for ordinary repairs and maintenance, approximately $18,000,000, against $22,000,000 in the preceding year, and interest on bonds and fixed charges of the subsidiary companies amounted to $73,176,522, against $109,171,152 for the year 1903. The total undivided surplus on December 31, 1904, was $61,365,446.

The gross receipts of the United States Steel Corporation in 1904 were $444,405,431, against $536,572,871 in 1903, a decrease of $92,167,440. In referring to the showing for 1904 the report says, in part: "The depression in the iron and steel trade, which, in common with all other lines of business, took place during the summer of 1903, continued until the late fall of 1904. In the latter part of the year 1904 there was a marked increase in the volume of business received, and this revival has continued."

The unfilled orders on the books on December 31, 1904, amounted to 4,696,203 tons of all kinds of manufactured products, in comparison with 3,215,123 tons at the close of 1903.

The monthly earnings of the subsidiary companies and of the corporation from April 1, 1901, to the end of 1904 were as follows, omitting cents:

Months	1901	1902	1903	1904
Jan.	....	$8,901,016	$7,425,775	$2,868,213
Feb.	....	7,678,583	7,730,361	4,540,673
March	....	10,135,858	9,912,571	6,036,346
April	$7,356,744	12,320,766	10,905,204	6,863,833
May	9,612,349	13,120,930	12,744,324	6,256,519
June	9,394,748	12,220,362	12,992,780	6,370,374
July	9,580,151	12,041,914	12,384,647	6,344,771
Aug.	9,810,881	12,972,729	10,918,174	6,202,958
Sept.	9,272,811	11,930,846	9,120,134	6,226,204
Oct.	12,205,774	12,652,707	7,675,141	7,250,204
Nov.	9,795,840	10,686,906	4,069,901	7,117,417
Dec.	7,758,298	8,646,146	3,292,140	7,099,010
Total	$84,787,596	$133,308,763	$109,171,152	$73,176,522

The average number of employees in the service of all the companies in 1904 was 147,343, against 167,709 in 1903. The total annual salaries and wages last year were $99,778,276, against $120,763,896 in 1903. The corporation has authorized improvements in the present year approximating $31,000,000.

Under the profit sharing plan, 8,429 employees subscribed at the end of 1904 for 17,973 shares of the preferred stock at $87.50 a share. For the three years during which the stock subscription plan has been in force 44,740 subscriptions have been received for a total of 97,168 shares.

The stockholders of the United States Steel Corporation at the end of 1904 numbered 67,522, against 79,957 at the close of 1903. "The Bulletin" of the American Iron and Steel Association, April 1, 1905.

Iron and Steel Institute. — The secretary of the Iron and Steel Institute announces the following program for the annual meeting to be held in London, May 11 and 12, 1905:

The retiring President, Andrew Carnegie, Esq., LL.D., will induct into the chair the president-elect, R. A. Hadfield, Esq.

The Bessemer Gold Medal for 1905 will be presented to Prof. J. O. Arnold (Sheffield).

The awards of the Andrew Carnegie Gold Medal and Research Scholarships for 1905 will be announced.

The president will deliver his inaugural address.

List of papers that are expected to be submitted:

(1) "On experiments on the Fusibility of Blast Furnace

Slags," by O. Boudouard, D.Sc., Carnegie Research Medallist, 1903 (Paris).

(2) "On Recent Developments of the Bertrand-Thiel Process," by J. H. Darby (Brymbo) and G. Hatton (Brierley Hill).

(3) "On the Application of Dry-Air Blast to the Manufacture of Iron," by James Gayley (New York). Supplement to paper read on October 26, 1904.

(4) "On the Effect Produced by Liquid Air Temperature on the Mechanical and Other Properties of Iron," by R. A. Hadfield (president).

(5) "On the Cleaning of Blast Furnace Gas," by Axel Sahlin (London).

(6) "On the Failure of an Iron Plate through Fatigue," by S. A. Houghton (London).

(7) "On the Continuous Steel-Making Process in Fixed Open-Hearth Furnaces," by S. Surzycki (Czenstochowa, Poland).

(8) "On Accidents due to the Asphyxiation of Blast Furnace Workmen," by B. H. Thwaite (London).

(9) "On the Behaviour of the Sulphur in Coke in the Blast Furnace," by Prof. F. Wüst, Ph.D., and P. Wolff (Aachen).

Reports on research work carried out during the past year will be submitted by C. O. Bannister (London), J. Dixon Brunton (Musselburgh), H. C. H. Carpenter (Teddington), J. C. Gardner (Oldbury), G. Dillner and A. F. Enström (Stockholm), E. G. L. Roberts and E. A. Wraight (London), Frank Rogers (Cambridge) and Walter Rosenhain (Birmingham), Andrew Carnegie Research Scholars.

The Bessemer Gold Medal. — Prof. J. O. Arnold, of the Metallurgical Department of Sheffield University College, has been awarded the Bessemer Gold Medal by the Council of the Iron and Steel Institute at its meeting of March 22, 1905. The medal will be presented to Professor Arnold at the annual meeting of the Institute, in London, May 11, 1905.

REVIEW OF THE IRON AND STEEL MARKET

The pig-iron statistics at the beginning of April showed that the month was entered with furnaces producing at the rate of about 23,200,000 gross tons of all kinds of pig iron annually. This surpasses even the remarkable records which were made earlier in the year, and is about 2,500,000 tons in excess of the maximum rate attained on the last movement, which reached its culmination in May, 1903.

While there is no question that the output of steel products is greater than at any previous time, the rather popular assumption that steel production is following pig-iron production is not altogether correct. The great basic open-hearth steel industry is using a much smaller proportionate amount of scrap from the outside than ever before, and the scrap used which originates in the steel works through crop ends, rejected portions of ingots, etc., simply forms an endless chain which goes to swell the statistics of steel ingot production and does not contribute to the tonnage of actual finished steel forms. With this understanding it is more easy to conceive that the enormous rate of pig-iron production can be maintained.

There has been very little fresh buying of pig iron or of finished steel products. By far the greatest percentage of products now being shipped is covered by old contracts, many of which were quite liberal in their terms as to tonnage and deliveries, so that fresh buying is not necessary in order to maintain the present pace through the summer. What will happen towards fall depends purely upon whether buyer or seller will be compelled to enter the market first.

Stocks of merchant pipe, wire products, sheets and tin plates in jobbers' or consumers' hands are considerably in evidence, and have resulted in some shading. In rails, plates and shapes there are no accumulations whatever, the mills rather being behind in their deliveries, so that prices are quite firm in these lines, and occasionally premiums are paid for small lots and prompt shipment.

Pig Iron. — On April 3 the United States Steel Corporation bought about 35,000 tons of Bessemer pig iron for April delivery, of which about 25,000 tons came from the Bessemer Furnace Association at $15.50, valley furnace, the price which has controlled all the purchases of the corporation on this movement, 2,000 tons from an outside valley interest at $15.40, and about 9,000 tons from some Hanging Rock furnaces, at $14.85, f. o. b. furnace, this low price being made in order to equalize with the valleys for Wheeling delivery, there being a difference of 65 cents in the freight. Most of the iron, however, has gone to Cleveland, making a delivered cost 5 cents less than would result from a price of $15.50, valley. The International Harvester Company early in the month came suddenly into the market and bought about 60,000 tons of foundry pig for second half delivery, a trifle over half being northern, at slight concessions from the ruling market on ordinary lots. The purchase was regarded as significant since this interest does not usually buy its second half iron until some time in June. Otherwise, the pig-iron market was very quiet during April. Minimum prices showed scarcely any decline, but prices on small lots showed a recession to the level prevailing on large lots. The furnaces are well sold up and are not making efforts to encourage purchases. There is, however, a disposition among buyers to look for lower prices. Current prices are, f. o. b. valley furnace: Bessemer and basic, $15.50; No. 2 foundry, $16.00; forge, $15.00. Delivered Pittsburg: Bessemer and basic, $16.35; No. 2 foundry, $16.85; forge, $15.85. F. o. b. Birmingham: No. 2 foundry, $13.50; gray forge, $12.50. Delivered Philadelphia: No. 2 X foundry, $17.50 to $17.75; standard gray forge, $16.00; basic, $16.75 to $17.00. Delivered Chicago: Northern No. 2 foundry, $17.25 to $17.50; southern No. 2 foundry, $17.15; malleable Bessemer, $17.50.

Steel. — Billets are very scarce, particularly forging billets and small billets. Ordinary soft-steel 4 x 4 billets are held at $24, Pittsburg, and sheet bars at $26.00. Forging billets and small billets are bringing as high as $28.00, Pittsburg. Most consumers of soft-steel billets are fairly well covered for the present. There is considerable inquiry for prices on foreign steel, but it is hardly likely that any business will result, as the best price on foreign billets, duty paid, seaboard, is about $28.50, and deliveries

could not, of course, be made for some time. Wire rods are firm at $34.00 to $35.00, f.o.b. Pittsburg.

Shapes. — Contracts for bridges and buildings are very heavy, the total tonnage booked in April being far in excess of that in March, although March was considered a normal month. Specifications are accordingly very heavy with the structural mills, on contracts placed for the season. On new business shape prices remain as follows, in carload and larger lots, f.o.b. Pittsburg: Beams and channels, 3-inch to 15-inch inclusive, angles 2 x 3 to 6 x 6 inclusive and zees, 1.60 cents per pound; tees 3-inch and larger, 1.65 cents; beams and channels over 15-inch, 1.70 cents.

Plates. — Specifications are still larger, the steel-car business which maintained the plate trade during the winter being reinforced by demand from more scattered sources. The steel car builders are still well filled with business, and have not been able to complete deliveries on contracts intended to be filled by the opening of navigation. In some instances premiums are paid for small lots for spot shipment, but on regular business the following prices continue to rule: Tank quality, quarter-inch and heaver, 6¼ to 14 inches wide inclusive, 1.50 cents per pound; over 14 inches and not over 100 inches wide, 1.60 cents; extra thin plates, extra wide plates and special qualities command the usual extras.

Merchant Bars. — There is very little demand for iron bars and the market is correspondingly weak. The rapid advance last year in iron bars, owing in part to the advances in the scrap market, is having its effect now, a number of users having turned to steel bars. Common iron bars are quoted at 1.65 cents per pound, Pittsburg, but are weak at that quotation. Steel bars are firm at 1.50 cents, Pittsburg, half extras.

Sheets. — The market on black sheets is not very firm at the advance made by the leading interest effective March 16, as the great bulk of the business was covered by contracts before the advance, and the new price is being shaded in some instances. Production is very heavy. Prices are as follows, in car load or larger lots, f.o.b. Pittsburg, all on No. 28 gauge: Black sheets, 2.40 cents; galvanized sheets, 3.45 cents; painted corrugated roofing, $1.75 per square; galvanized corrugated roofing, $2.95 per square.

Scrap. — The scrap market is decidedly weaker in all districts, partly because the better weather has brought out more material, and partly because consumers are not buying to the extent that was expected. The rolling mills are experiencing slack business, besides having become rather overloaded with scrap in the winter; the foundries are not very busy, and the basic open-hearth steel works are buying much less than would naturally be expected, considering the activity in the steel trade. Small lots of heavy melting stock have been selling at $16.00 to $16.25, delivered Pittsburg, but a large lot could hardly be disposed of within this range. Other grades of scrap are quoted as follows, delivered Pittsburg: bundled sheet scrap, $15.00 to $15.25; cast-iron borings, $10.25 to $10.50; cast scrap, $15.00 to $15.50.

Coke. — The very heavy production in the past month or two is having its effect, prices being easier and a trifle lower on prompt coke than on contracts. Strictly Connellsville furnace coke is held at $2.00 to $2.10, but an occasional prompt lot might be picked up at $1.90 or $1.95, while strictly Connellsville foundry coke is bringing $2.60 to $3.00 according to conditions.

STATISTICS

Production of Open-Hearth Steel in the United States in 1904.* — The American Iron and Steel Association has received complete statistics of the production of open-hearth steel in the United States in 1904. The production was larger than in 1903 or in any preceding year.

The total production of open-hearth steel ingots and castings in the United States in 1904 was 5,907,666 gross tons, against 5,829,911 tons in 1903, an increase of 77,755 tons, or 1.3 per cent. The following table gives the production of open-hearth ingots and castings by states since 1901:

States	1901 Gross tons	1902 Gross tons	1903 Gross tons	1904 Gross tons
New England	170,876	179,923	169,209	195,901
New York and New Jersey	82,985	92,763	104,598	165,986
Pennsylvania	3,594,763	4,375,364	4,442,730	4,306.498
Ohio	184,943	278,854	369,349	480,406
Illinois	398,522	435,461	422,919	358,215
Other states	224,220	325,364	321,106	400,660
Total	4,656,309	5,687,729	5,829,911	5,907,666

The open-hearth steel made in 1904 was produced by 115 works in 16 states, — Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Maryland, Tennessee, Alabama, Ohio, Indiana, Illinois, Wisconsin, Missouri, Colorado and California. One hundred and eleven works in 17 states made open-hearth steel in 1903.

The production of open-hearth steel ingots in 1904, excluding castings, amounted to 5,605,332 gross tons, against 5,429,563 tons in 1903, an increase of 175,769 tons.

In 1903 4,734,913 tons of open-hearth steel were made by the basic process and 1,094,998 tons were made by the acid process, while in 1904 the production by the basic process amounted to 5,106,367 tons and by the acid process to 801,299 tons. In

* "The Bulletin" of the American Iron and Steel Association, March 15, 1905.

the following table, the production by states of both acid and basic open-hearth steel ingots and castings in 1904 is given:

States — Gross tons	Basic open-hearth steel	Acid open-hearth steel	Total. Gross tons
New England	147,390	48,511	195,901
New York and New Jersey	139,791	26,195	165,986
Pennsylvania	3,667,673	638,825	4,306,498
Ohio	427,948	52,458	480,406
Illinois	341,073	17,142	358,215
Other states	382,492	18,168	400,660
Total	5,106,367	801,299	5,907,666

There was a decrease in the production of acid steel in 1904 as compared with 1903 of 293,699 tons, or over 26.8 per cent, but an increase in the production of basic steel of 371,454 tons, or over 7.8 per cent.

The total production of open-hearth steel castings in 1904, included above, amounted to 302,334 gross tons, of which 98,919 tons were made by the basic process and 203,415 tons were made by the acid process. In 1903 the production of open-hearth steel castings amounted to 400,348 tons, of which 134,879 tons were made by the basic process and 265,469 tons by the acid process. The decrease in direct castings in 1904 as compared with 1903 amounted to 98,014 tons. The following table gives the production of open-hearth steel castings by the acid and basic processes in 1904 by states.

States — Gross tons	Basic castings	Acid castings	Total Gross tons
New Eng., N. Y. and N. J.	17,193	27,285	44,478
Pennsylvania	5,831	128,579	134,410
Ohio, Illinois and other states	75,895	47,551	123,446
Total	98,919	203,415	302,334

Iron and Steel Statistics for 1904.* — We give below such iron and steel statistical information for 1904 as we have been able to collect up to the present time. For comparison, the

* "The Bulletin" of the American Iron and Steel Association, March 15, 1905.

corresponding figures for 1903 are given. Unless otherwise mentioned, the tons used are gross tons. Some of the figures for 1904 are subject to revision in our annual statistical report.

Products	1903	1904
Shipments Lake Superior iron ore, tons	24,289,878	21,822,839
Shipments Connellsville coke, net tons	13,345,230	12,427,468
Production of pig iron, tons	18,009,252	16,497,033
Unsold pig iron stocks, December 31, tons	598,489	446,442
Production of Bessemer steel, tons	8,592,829	7,859,140
Production of all kinds of rails, tons	2,992,477	2,284,761
Production of open-hearth steel, tons	5,829,911	5,907,666
Imports of iron ore, tons	980,440	487,613
Imports of iron and steel, values	$41,255,864	$21,621,970
Exports of iron and steel, values	$99,035,865	$128,553,613

With the exception of open-hearth steel, the above table shows a reduction in all lines of shipments and production in 1904 as compared with 1903, and a shrinkage of over 47 per cent in our iron and steel imports, and of more than 50 per cent in our imports of iron ore. It is only by the presentation of the above comparative table that we are able to appreciate fully the great reaction that occurred in our iron and steel industries in 1904.

The Production of Pig Iron by Grades.* — The following table gives the production of pig iron in 1903 and 1904 by grades in gross tons:

Grades — Gross tons	1903	1904
Bessemer and low phosphorus	9,989,908	9,098,659
Basic pig iron made with mineral fuel	2,040,726	2,483,104
Forge pig iron	783,016	550,836
Foundry and high silicon	4,409,023	3,827,229
Malleable Bessemer pig iron	473,781	263,529
White, mottled and miscellaneous	120,137	53,284
Spiegeleisen	156,700	162,370
Ferro-manganese	35,961	58,022
Total	18,009,252	16,497,033

The Bessemer figures include low-phosphorus pig iron, that is, iron running below 0.04 per cent in phosphorus. Pig iron

* "The Bulletin" of the American Iron and Steel Association, March 15, 1905.

containing from 0.04 to 0.10 per cent of phosphorus is classified as Bessemer. The basic figures are confined strictly to pig iron made with mineral fuel. A few thousand tons of castings direct from the furnace are included in the totals for white and mottled and miscellaneous grades of pig iron for 1903 and 1904. Ferro-silicon and high-silicon pig iron are included in the foundry figures.

Of the total production of pig iron in 1904, over 55.1 per cent was Bessemer and low-phosphorus as compared with over 55.4 per cent in 1903; nearly 23.2 per cent was foundry, against 24.4 per cent in 1903; 15 per cent was basic, against over 11.3 per cent in 1903; 3.3 per cent was forge, against 4.3 per cent in 1903; 1.3 per cent was spiegeleisen and ferro-manganese, against 1.06 per cent in 1903; and nearly 1.6 per cent was malleable Bessemer, against 2.6 per cent in 1903. The production of white and mottled and miscellaneous grades of pig iron and of castings made direct from the furnace amounted to less than 1 per cent in both years.

In 1904 the production of low-phosphorus pig iron amounted to 190,946 tons, against 200,422 tons in 1903. In 1904 low-phosphorus pig iron was made in New York, Pennsylvania and Tennessee. The following table gives the production by states of Bessemer and low-phosphorus and basic pig iron in 1903 and 1904:

States — Gross tons	Bess. and low-phos.		Basic pig iron	
	1903	1904	1903	1904
New York	129,323	250,483	34,516	1,233
New Jersey	....	....	83,286	112,455
Pennsylvania	5,213,143	4,511,999	1,417,253	1,805,747
Maryland	321,784	292,642	....	....
Virginia	1,000	....	90,543	45,742
West Virginia	198,688	267,505	....	....
Tennessee	26,856	25,209	5,176	....
Alabama	2,299	....	172,280	273,587
Ohio	2,422,676	2,138,442	190,840	179,560
Illinois	1,386,683	1,424,030	....	53,338
Michigan	3,520	17,976	....	....
Wisconsin	74,080	37,287	....	....
Minnesota	33,740	20,768	....	....
Missouri	....	....	17,000	11,442
Colorado	176,116	112,318	29,832	....
Total	9,989,908	9,098,659	2,040,726	2,483,104

A small quantity of charcoal basic pig iron is not included in the basic figures. The production of foundry and forge pig iron by states in 1903 and 1904 was as follows, in gross tons:

States — Gross tons	Foundry pig iron		Forge pig iron	
	1903	1904	1903	1904
Massachusetts	3,265	3,149	....	....
Connecticut	14,501	8,922	....	....
New York	304,667	281,419	37,986	33,675
New Jersey	85,257	103,454	25,750	32,071
Pennsylvania	948,957	840,407	433,925	297,307
Maryland	2,460	799	326	....
Virginia	413,403	253,812	29,551	9,918
West Virginia	43	13	....	3,427
Kentucky	98,600	36,297	2,453	600
Tennessee	350,966	253,185	23,159	19,743
North Carolina	6,779	....	619	....
Georgia	59,910	52,658	5,765	8,824
Texas	11,408	5,100	....	....
Alabama	1,194,556	1,085,935	155,937	76,850
Ohio	416,850	459,354	61,904	66,148
Illinois	115,223	107,236	5,641	....
Michigan	239,369	201,849	....	....
Wisconsin	112,656	113,180	....	2,273
Mo., Col. and Wash.	30,153	20,460	....	....
Total	4,409,023	3,827,229	783,016	550,836

Included in the 3,827,229 tons of foundry pig iron made in 1904 are 69,730 tons of ferro-silicon, produced in Pennsylvania, Virginia, West Virginia, Kentucky and Ohio, a small part of which was made with electricity. In 1903, 51,516 tons of ferro-silicon were made. Pig iron containing 7 per cent of silicon and over is classified as ferro-silicon. Virtually all the charcoal pig iron made is classified as foundry pig iron. Alabama is now the leading producer of foundry pig iron and Pennsylvania of forge.

The production of malleable Bessemer pig iron in 1904 amounted to 263,529 tons, against 473,781 tons in 1903. In 1904 the production of white and mottled and other miscellaneous grades of pig iron and direct castings amounted to 53,284 tons, against 120,137 tons in 1903.

The production of spiegeleisen and ferro-manganese by states in 1903 and 1904 was as follows, in gross tons:

States — Gross tons	Spiegeleisen		Ferro-manganese	
	1903	1904	1903	1904
New Jersey	15,346	11,242	......	....
Pennsylvania	76,493	103,773	34,871	57,076
Tennessee	....	....	....	946
Alabama	24	....	1,090	....
Illinois	57,955	39,799	....	....
Colorado	6,882	7,556	....	....
Total	156,700	162,370	35,961	58,022

The figures given for ferro-manganese for 1904 include a small quantity of ferro-phosphorus made in Tennessee. Ferro-phosphorus was not reported to us for 1903, but a small quantity was reported by Alabama in 1902. Spiegeleisen usually contains from 9 to 22 per cent of manganese, and ferro-manganese from 45 to 82 per cent.

Production of All Kinds of Rails in 1904.* -- The production of all kinds of rails in the United States in 1904 as ascertained by the American Iron and Steel Association amounted to 2,284,711 gross tons, against 2,992,477 tons in 1903, a decrease of 707,766 tons, or 23.6 per cent. In the following table the production of all kinds of rails in 1904 is given by states:

Gross tons	Bessemer	Open-hearth	Iron	Total
Pennsylvania	801,657	20,451	....	822,108
Other states	1,336,300	125,432	871	1,462,603
Total	2,137,957	145,883	871	2,284,711

The production of Bessemer steel rails in 1904 amounted to 2,137,957 gross tons, against 2,946,756 tons in 1903, a decrease of 808,799 tons, or over 27.4 per cent. In the following table the production of Bessemer steel rails is given by states from 1901 to 1904. Rails rolled from purchased blooms, crop ends and "seconds," and rerolled, or renewed, rails are included:

* The Bulletin of the American Iron and Steel Association, April 1, 1905.

Gross tons	1901	1902	1903	1904
Pennsylvania	1,406,008	1,148,425	1,186,284	801,657
Other states	1,464,808	1,786,967	1,760,472	1,336,300
Total	2,870,816	2,935,392	2,946,756	2,137,957

The production of Bessemer steel rails by the makers of Bessemer steel ingots, included above, amounted to 2,084,688 tons in 1904, 2,873,228 tons in 1903, 2,876,293 tons in 1902, 2,836,273 tons in 1901, 2,361,921 tons in 1900 and 2,240,767 tons in 1899. In the following table we give the total production of all kinds of Bessemer steel rails from 1901 to 1904, the rails rolled by makers of domestic ingots being separated from those rolled by companies which did not operate Bessemer converters:

Gross tons	1901	1902	1903	1904
By makers	2,836,273	2,876,293	2,873,228	2,084,688
By all others	34,543	59,099	73,528	53,269
Total	2,870,816	2,935,392	2,946,756	2,137,957

The total production of open-hearth steel rails in 1904 was 145,883 tons, against 45,054 tons in 1903, 6,029 tons in 1902, 2,093 tons in 1901 and 1,333 tons in 1900. Alabama rolled almost all the open-hearth rails that were rolled in 1904, Pennsylvania and Colorado rolling the remainder. Over 116,000 tons of the open-hearth rails rolled in 1904 weighed between 45 and 85 pounds per yard, and over 8,000 tons weighed 85 pounds or over. The remainder weighed less than 45 pounds.

The production of iron rails in 1904 was 871 tons, all rolled in Tennessee and Alabama, and all weighing less than 45 pounds to the yard.

The total production in 1904 of rails weighing under 45 pounds to the yard amounted to 291,883 tons; of rails weighing 45 pounds and less than 85 pounds, 1,320,677 tons; and of rails weighing 85 pounds or over, 672,151 tons.

RECENT PUBLICATIONS

Steam-Boilers, by H. de B. Parsons. Second Edition. 375 6 × 9-in. pages; 157 illustrations. Longmans, Green & Co. New York. 1905. Price, $4.00. — The well-known author of this book presents in these pages the substance of a series of lectures delivered at the Rensselaer Polytechnic Institute, Troy, N. Y., in which he is professor of steam engineering. The book is divided into sixteen chapters, devoted to the following subjects: Physical Properties, Combustion, Fuels, Furnaces and Efficiency of Boilers, Boilers and Steam Generators, Chimney Draft, Materials, Boiler Details, Boiler Fittings, Mechanical Stokers, Artificial Draft, Incrustation, Corrosion, General Wear and Tear, Explosions, Chimney Design, Smoke Prevention, Testing, Boiler Coverings, and Care of Boilers. These subjects are treated with much clearness and authority. The excellent chapters on combustion and fuels should be of interest to a large class of people. The book is well bound, printed and illustrated.

Smoke Prevention and Fuel Economy, by William H. Booth and John B. C. Kershaw. 194 $5\frac{1}{2} \times 8\frac{1}{2}$-in. pages; 75 illustrations. The Norman W. Henley Publishing Company. New York. 1905. Price, $2.50. — It is not necessary to insist upon the importance of the subject with which this book deals. As the authors of this book well say, the suppression of smoke is called for both on humanitarian and economic grounds. That this can be effectively done is not to be doubted after reading this book, in which the authors express their belief that even bituminous coal is capable of perfect combustion, and that black smoke is merely so much evidence of improper design. The book contains four chapters, dealing with the Chemistry of the Combustion Process, the Present Methods of Burning Fuels and Their Defects, Improved Methods of Burning Fuels, and the Examination of the Waste Gases and Control of the Combustion Process. An appendix is added, dealing with

Patents, Abstracts, Fuel Analysis and Miscellaneous Abstracts. The book is a timely one, which should be read by all those interested in the prevention of smoke, and this should mean every one concerned industrially with the consumption of fuels.

Electric Furnaces and their Industrial Applications, by J. Wright. 287 $5\frac{1}{2} \times 8\frac{1}{2}$-in. pages; 57 illustrations. The Norman W. Henley Publishing Company. New York. 1905. Price, $3.00. — The following titles of the fourteen sections into which the book is divided will clearly indicate its scope: Historical and General, Arc Furnaces, Resistance Furnaces and Typical Processes, Iron and Steel Production in the Electric Furnace, Phosphorus Manufacture in the Electric Furnace, Glass Manufacture in the Electric Furnace, Electrolytic Furnaces and Processes, Miscellaneous Electric Furnaces and Processes, Laboratory Furnaces and Experimental Research, Tube Furnaces, Terminal Connections and Electrodes, Efficiency and Theoretical Considerations, Measurement of Furnace Temperatures. There exists at the present time a widespread interest in electric furnaces and their products; by their use some industries have been revolutionized, while new ones have been created. The author presents in this book many data which will be found of much interest and assistance to those desirous of acquiring a knowledge of what has already been done with the electric furnace and of its possibilities. While far from being exhaustive, this book is, nevertheless, a very instructive and useful one.

Laboratory Hand-Book of Electro-Technology, by W. Brown and R. G. Allen, respectively lecturer and assistant in electrotechnology at the Royal College of Science, Dublin. 159 $4\frac{1}{2} \times 7$-in. pages; 57 illustrations. Sealey, Bryers & Walker. Dublin. 1904. Price, 5*s*. — This book is intended to provide the student with a practical guide for his work in the electrical laboratory. It consists in the description of fifty-eight laboratory experiments, including the determination of H, the horizontal component of the earth's magnetic force, the determination of the constant of galvanometers and voltmeters, the measurement of the E. M. F. of cells, the measurement of resistance and of insulation resistance, the ballistic galvanometer, the magnetic properties of iron and measurement of capacity, the

measurement of self-induction and mutual induction, the measurement of power and some preliminary experiments with dynamos, motors, alternators and transformers. This book should prove of much value and interest to students of electricity.

Transactions of the Faraday Society. Vol. I, Part 1. 118 $6 \times 9\frac{1}{2}$-in. pages; illustrated. Published by the Faraday Society, London. January, 1905. Price, 10*s.* 6*d.* — The Faraday Society was founded in 1903 to promote the study of electrometallurgy, electrochemistry, chemical physics, metallography and kindred subjects. This is the initial number of the quarterly transactions to be published by the society. They will contain in full papers which have been read with the discussion thereon, and monthly proceedings containing reports and notices of meetings. Patents bearing on electrochemistry and electrometallurgy, and the sections from science abstracts which deal with physical chemistry and its applications will also be published. Members also receive, free of charge, the Transactions of the American Electro-Chemical Society, of which at present two volumes are published annually. The subscription to the Faraday Society is £2 a year for members, and £1 a year for students; members also pay an entrance fee of £1.

The work done by the Faraday Society during the first two years of its existence has been most creditable and gives fair promise that this association will become an important factor in the advancement of a subject teeming with important industrial possibilities. It should have the good wishes and good will of all engineers and scientists.

Proceedings of the American Society for Testing Materials. Vol. IV. Edited by the secretary and published by the society. Philadelphia. 1904. 655 6×9-in. pages; illustrated. This volume contains the proceedings of the seventh annual meeting of the society, held at Atlantic City, N. J., June 16, 17 and 18, 1904.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

782,298. Spout for Blast Furnaces. — James T. White, Anaconda, Mont., assignor of one half to Charles S. Palmer, Anaconda, Mont. A furnace spout comprising a hollow shell provided in its outer side near one end with a plurality of water-inlet supply openings arranged in alignment and longitudinally of the spout, and near the other end with a water-outlet opening, and heads detachably connected with the shell.

782,334. Hot-Air-Blast Stove. — Charles M. Gunn, Sausalito, and William D. Mulloy, Canyon, Cal., assignors to Union Iron Works, San Francisco, Cal. In hot-air-blast stove, the combination with the heating chamber, of a series of air-circulating tubes suspended therein, comprising vertically arranged communicating coils, and solid connections between the tubes at the upper and lower ends, comprising heads extending over and connected to the communicating ends of the tubes, said heads having inwardly turned flanges between adjacent coils and bolts securing adjacent flanges.

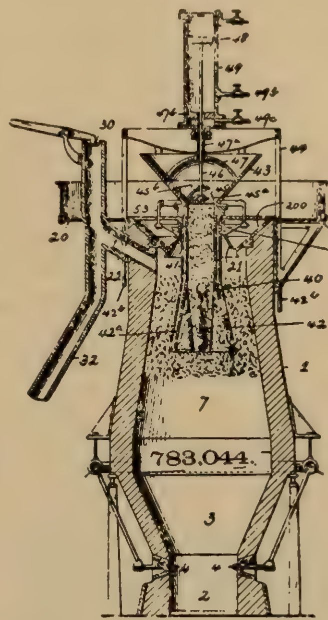
782,697. Continuous Heating-Furnace. — Josef Reuleaux, Wilkinsburg, Pa., assignor to Alexander Loughlin, Sewickley, Pa. A furnace having in combination therewith bearings arranged longitudinally thereof, a hearth intersecting said bearings and on to which the billets are received from the bearings, said hearth having spaces therein in line with the bearings for the admission of the gases against the under sides of the billets on the hearth, and means for pushing the billets over the bearings and hearth.

782,875. Forge. — Henry Price, Buffalo, N. Y., assignor to Chilion M. Farrar and George M. Trefts, Buffalo, N. Y. In a forge, the combination with a series of spaced permanent grate-bars flush with the cover of the grate, of a series of rotatable auxiliary grate-bars operating between the permanent grate-bars to vary the intensity and area of the blast.

783,200. Foundry or Casting Plant. — Joseph W. Henderson, Baltimore, Md. In a foundry or plant for the manufacture of castings, the combination of the cupolas at one end of the foundry building; a plurality of parallel floor-tracks extending in a direction toward said cupolas; a transfer-track which extends crosswise of the cupola ends of said parallel tracks, then back to and crosswise of the opposite ends of said tracks; cranes at said opposite ends of said parallel tracks; tracks connecting the ends of the parallel tracks with said transfer-track; over-

head tracks in alignment with said connecting-tracks, and having travelers which move toward and away from said parallel tracks, and flasks mounted on rollers.

783,044. PROCESS OF SMELTING ORES IN BLAST FURNACES.—Joseph E. Johnson, Jr., Longdale, Va. A process of smelting ores in a blast furnace, which consists in feeding separate bodies of ore and fuel into the furnace, smelting the charge and increasing the amount of heat available for smelting, and especially for those reactions which require a high temperature, by supplying a blast containing an excess of oxygen and utilizing the heat in the fuel by passing the gases escaping from the furnace through the incoming body of ore and maintaining them out of contact with the incoming fuel, the waste gases thus being high in carbon dioxide and low in carbon monoxide and nitrogen.



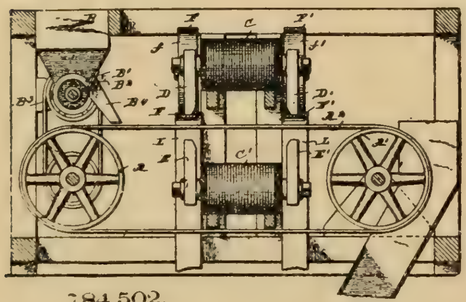
783,234. HOT-BLAST STOVE. — Frank L. White, Pittsburg, Pa., assignor of one half to John Kernan, Pittsburg, Pa. A hot-blast stove comprising a plurality of parallel arches presenting inclined upper faces, a plurality of brick girders, disposed transversely of said arches projecting thereabove, said girders having inclined faces resting upon said arches and substantially vertical end faces abutting against each other, the upper edge of said girders aligning to form continuous flat faces, and layers of brick laid upon said last flat faces and presenting regenerative passages.

783,778. FURNACE ARCH. — George L. Davison and David R. Mathias, Chicago, Ill., assignors to Protected Furnace Port Company, Chicago, Ill., a corporation of Illinois. In an open-hearth furnace, the combination with the main chamber of upper and lower flues, leading into one end thereof, and a horizontally and transversely extending divisional arch separating said upper and lower flues at or near their point of entrance to the main chamber, said divisional arch comprising an upper layer of refractory material and an underlying transversely extending water-cooled structure, underlying and directly supporting substantially all parts of the refractory material of those portions of the divisional arch which form the point of conflux of said upper and lower flues.

784,004. HOT SYSTEM ROLLING-MILL. — William Kent, Youngstown, O., assignor of one half to Noah Kent, Struthers, O. The combination of a set of rolls and two portable furnaces, one on each side thereof, having each two openings, whereby to feed the rolls from one, and at the same time take from the rolls into the other, said furnaces having means to retain and heat the metal in the intervals between passages through the rolls.

784,124. PROCESS OF HARDENING IRON. — Ferdinand L. Ramon, San Francisco, Cal., assignor of one half to Percy D. Bailey, San Francisco, Cal. A process of hardening iron, which consists in forming an alloy of iron and aluminum by placing the metals in a crucible, heating the same to white heat, then placing on the metals a small quantity of sulphur and reducing such metals to a molten state by the application of additional heat, so as to be ready for pouring for the formation of the finished product.

784,171. PROCESS OF CARBURIZING STEEL PLATES. — Andrew F. Mitchell, Homestead, Pa., assignor of seven twentieths to William H. Jones, Homestead, Pa. A process of carburizing armor-plates, which consists in supporting a plate upon refractory material, arranging upon the upper face of said plate a sectional frame or box for confining the carbonaceous material, luting the lower edges of the frame sections with refractory material, placing sufficient carbonaceous material within the frame to extend above the upper edge thereof, placing another plate upon the carbonaceous material, luting the upper edges of the frame, between the frame and the upper plate, and submitting plates thus prepared to heat in a furnace.


784.502.

784,502. MAGNETIC ORE SEPARATOR. — Lewis G. Rowand, Camden, N. J., assignor to Wetherill Separating Company. In a magnetic ore-separator, the combination of a conveyor-belt adapted to convey the material to be treated, of magnets above and below said belt, the pole pieces of opposite magnets being in proximity to the conveyor-belt, the upper magnet having the stronger magnetic field.

784,535. MOLDING MACHINE. — Harriet A. Battenfeld, Cleveland, O., assignor to the Berkshire Manufacturing Company, Cleveland, O. In a molding machine, the combination with a reciprocating bed adapted to carry a flask, of a flask, a hopper, pressing mechanism, means whereby the flask on said bed may be automatically filled from said hopper, may be operated upon said pressing mechanism and may be moved out of range thereof, and means carried by said bed for closing the opening in said hopper.

784,536. MOLDING MACHINE. — John N. Battenfeld and Harriet A. Battenfeld, Cleveland, O., assignors to the Berkshire Manufacturing Company, Cleveland, O. In a molding machine, the combination with a reciprocating bed of a press, a pattern plate carried by said bed, a vibrator carried by said plate, valve mechanism carried by said bed for controlling said vibrator, and means for operating said valve mechanism to start the vibrator as the bed is leaving the press and for turning off the pressure before it reaches normal or rest position.

E. H. SANITER

SEE PAGE 564

The Iron and Steel Magazine

*". . . . . . Je veux au mond publier
d'une plume de fer sur un papier d'acier."*

Vol. IX June, 1905 No. 6

COPPER ALLOYS *

SPECIAL BRASSES AND QUENCHING OF BRONZE

By L. GUILLET

Translated from the French for The Iron and Steel Magazine

THESE researches were conducted at the works of the Société Métallurgique de la Bonneville (Eure) and in the laboratories of De Dion et Bouton.

Ordinary Brasses. — Before taking up the special brasses, it seems necessary to recall in a few words the constitution, the properties and the manufacture of ordinary brass, that is, of alloys of copper and zinc.

Constitution of Ordinary Brass. — In the curves of fusibility of alloys the maximum points indicate definite compounds, while the minimum points correspond to eutectic alloys. The fusibility curve of copper zinc alloys, as determined by Mallet, Charpy and more recently by Shepherd, is composed of two branches which meet at a point corresponding to the compound CuZn. It yields but little information concerning the constitution. Several transformation points have been detected in these alloys below the solidification point. This fact, first observed by Roberts-Austen, was studied by Heycock and Neville and later by Shepherd. The study of the micro-structure of these alloys has resulted in a more practical knowledge of their constitution. This work has been done by Le Chatelier, Behrens, Charpy and Shepherd. The results obtained are, briefly, as follows:

* "Revue de Métallurgie," February, 1905.

From 100 to 67 per cent copper, dentrites recalling those of bronze, and which would form the *a* solution of Shepherd containing from 64 to 100 per cent copper. (See Figs. 1 and 2.)

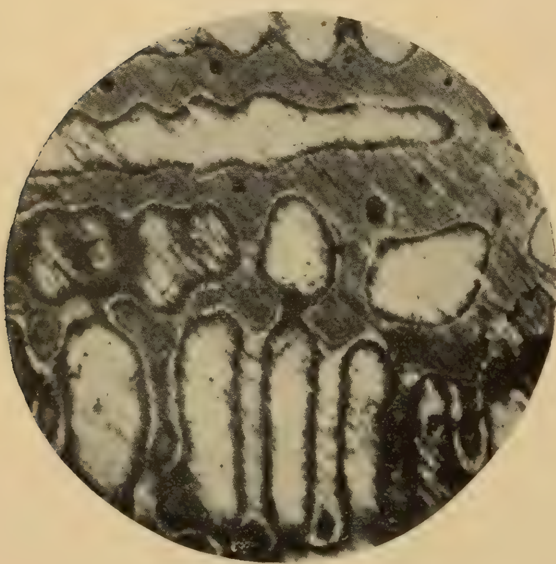


FIG. 1. Cu, 92%; Zn, 8%; 200 d.

FIG. 2. Cu, 67%; Zn, 33%; 200 d.

From 65 to 54 per cent copper, large crystals until now supposed to be the definite compound ZnCu, but which Shepherd believes to be the solid solution *α* surrounded by the solution *β*, the latter containing from 51 to 53 per cent copper. (See Fig. 3.)

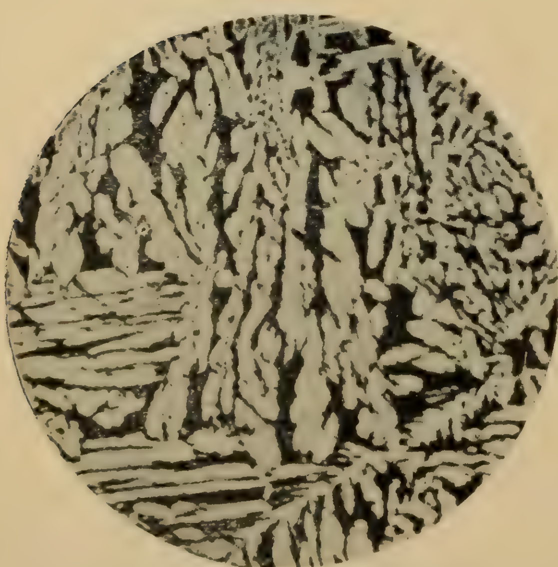


FIG. 3. Cu, 59%; Zn, 41%; 200 d.

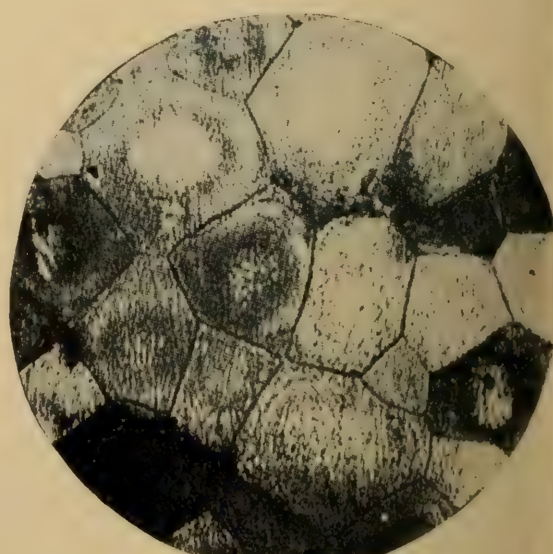


FIG. 4. Cu, 52%; Zn, 48%; 200 d.

From 54 to 51 per cent copper, solid solution (pure β-solution) of Shepherd. (See Fig. 4.)

From 51 to 40 per cent copper, solid solution ($\beta + \gamma$) of Shepherd. γ-solution containing from 31 to 40 per cent copper.

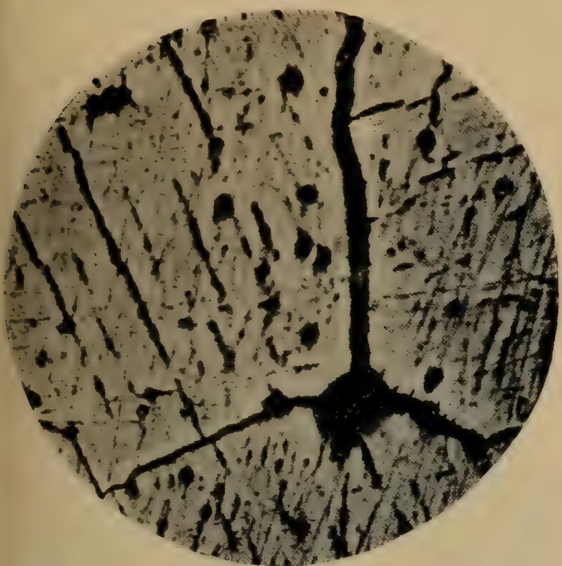


FIG. 5. Cu, 23%; Zn, 77%; 200 d.

FIG. 6. Cu, 20.5%; Zn, 79.5%; 200 d.

From 40 to 30 per cent copper, solid solution γ of Shepherd.

From 30 to 20 per cent copper, solid solution γ and ε, the latter solution containing from 13 to 19 per cent of copper (Figs. 5 and 6). Laurie, Herschkowitch, Charpy had indicated the definite compound Zn_2Cu.

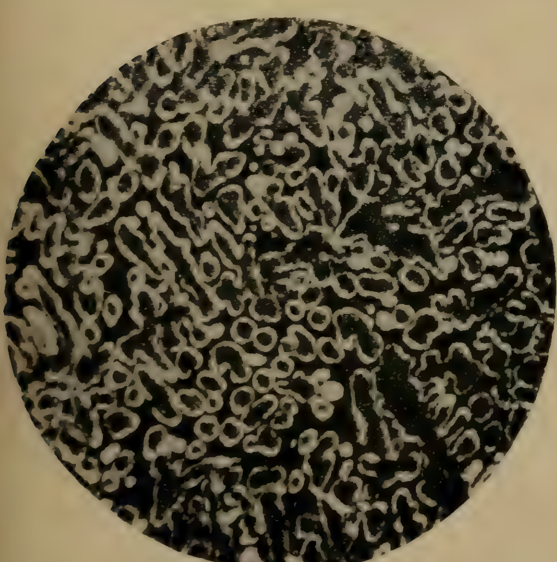


FIG. 7. Cu, 10.26%; Zn, 89.74%; 200 d.

FIG. 8. Cu, 6.60%; Zn, 93.40%; 200 d.

From 20 to 0 per cent copper crystals of Zn_4Cu after Shepherd; from 20 to 13 per cent copper, solution ε (Fig. 7); from 13 to 2.50 per cent copper solution ε and η (Fig. 8); from 2.5 to 0 per cent copper, solution η, which contains from 0 to 2.50 per cent copper.

The following is another interesting point to be noted: A brass containing for instance 67 per cent of copper is composed of slightly different solid solutions, but, after annealing at 600° C., twin crystals are found, observed first by Charpy, and from which Shepherd infers that annealing made the solution homogeneous. The higher the temperature above 600°, the larger the polyhedric grains. (See Figs. 9, 10 and 11.)

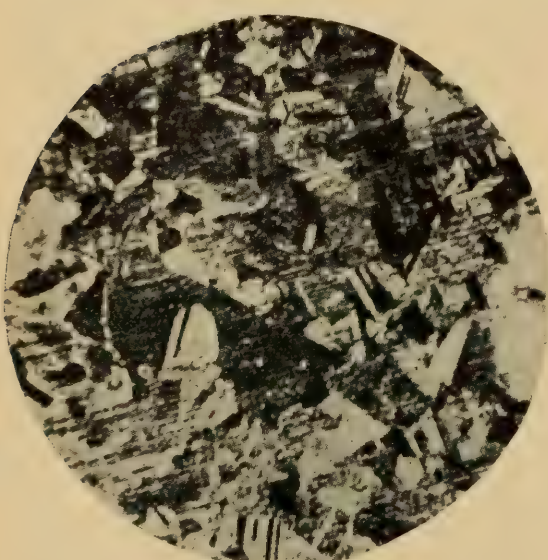


FIG. 9. Cu, 67%; Zn, 33%; 200 d.

FIG. 10. Cu, 67%; Zn, 33%; 200 d.

Mechanical Properties of Ordinary Brass. — These properties have been carefully studied by Charpy, who used forged and annealed test bars. His results are shown graphically in Diagram No. 1.

Manufacture of Brass. — The industrial production of an alloy always includes three steps:

1. The preparation of the alloy in a molten condition.
2. The casting of the alloy.
3. The working of the alloy in some marketable shape.

To prepare the alloy we may use new copper and zinc, which is very rare, or copper and zinc scrap, at least to a certain extent. The war department allows the use of a certain quantity

of scrap for the manufacture of cartridge brass, an alloy made up of 67 per cent of copper and 33 per cent of zinc. The melting is done in crucibles for small quantities, and in reverberatory furnaces for larger amounts. The metal may be cast in castings of any desired shape, or as ingots to be further worked. Rectangular ingots are used for rolling plates, and round ones for the rolling of bars, wire, etc. If the metal is to be cold rolled, long bars of small diameters are cast, while if it is to be hot rolled, ingots of much larger diameter are cast. When the brass contains more than 58 per cent copper, it must generally be cold worked. The advantage of hot over cold rolling is self evident.

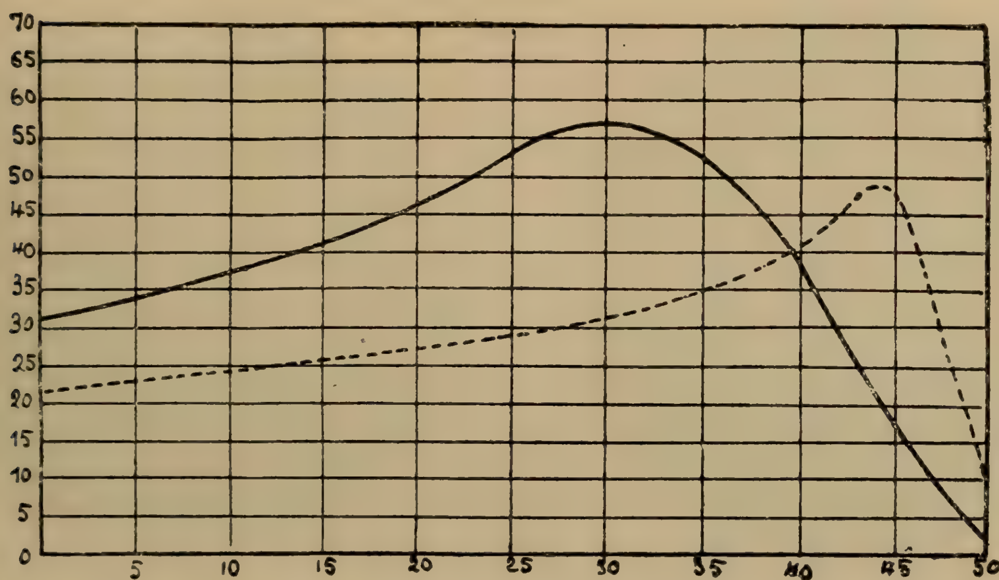


DIAGRAM I. Relation between the tenacity, elongation and the percentage of zinc in Copper Zinc Alloys

In cold working the metal must be annealed and pickled after each reduction.

Special Brasses. — By special brass is meant an alloy of copper and zinc containing one or more other elements purposely introduced to secure some special properties.

The following special brasses have been studied: (1) Lead brass; (2) tin brass; (3) aluminum brass; (4) manganese brass.

The experiments included micrographic and mechanical tests, and both cast bars and forged and annealed bars were used, for it is evident that in order to ascertain the influence of a certain element, the alloys studied should receive exactly the

same thermal treatment, and a uniform annealed condition can be secured more readily than a forged one. The test bars of the forged and annealed alloys were prepared at the "Usines Métallurgiques de la Bonneville." The cast bars were cut from cylinders 80 millimeters in diameter. Special brasses present much industrial importance because of their mechanical properties and the resistance they offer to certain chemical agents such as sea water and superheated steam. The following figures illustrate the importance of the last consideration. A sample of brass at 15° C. had a tenacity of 38 kilograms per square millimeter, an elastic limit of 15 kilograms and an elongation of

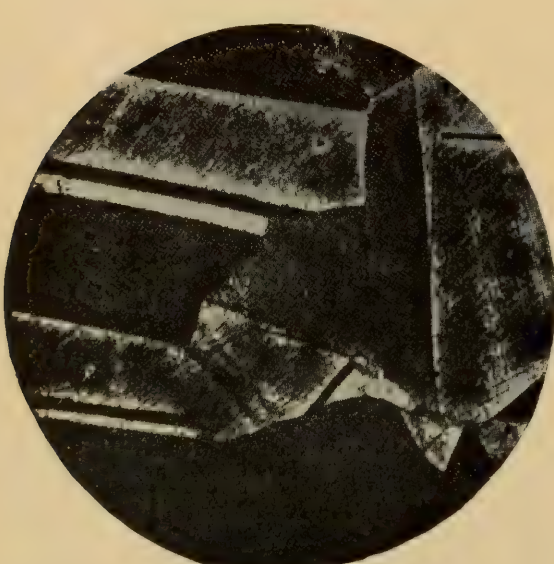


FIG. 11. Cu, 67%; Zn, 33%; 200 d.

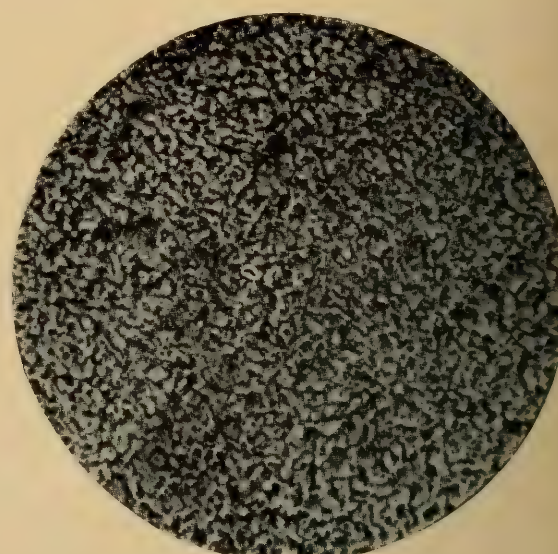


FIG. 12. Cu, 59%; Zn, 40%; Pb, 1%; 200 d.

20 per cent, while at 215° C., the tenacity was 29 kilograms, its elastic limit 12 kilograms and its elongation 21 per cent.

Lead Brass. — Theoretical Study. Ordinary brass generally contains from 0.5 to 3 per cent of lead. This small amount of lead is not merely introduced to decrease the cost of the alloy but also to make its working easier. The microscopical examination of brasses containing increasing amounts of lead show that the latter metal failing to alloy with the copper and zinc causes an increasing solidification of the characteristic crystals of the forgeable brasses. (See Figs. 12, 13 and 14.) The influence of lead is, therefore, to decrease the importance and number of the large, rounded crystals, and this explains why its presence

facilitates the turning and even the forging of the metal. When too large a proportion of lead is present, however, it results in a marked liquation and the alloy ceases to be homogeneous. As much as 5 per cent of lead may be added without liquation, but the fracture assumes then a dull gray color and shows a very small, close grain. After working, however, the metal has a beautiful yellow tint, even brighter than an alloy containing 60 per cent of copper and no lead.*

With more than 5 per cent of lead, the alloy is difficult to work. If it be attempted to roll it hot, it frequently happens

FIG. 13. Cu, 57%; Zn, 40%; Pb, 3%; 200 d.

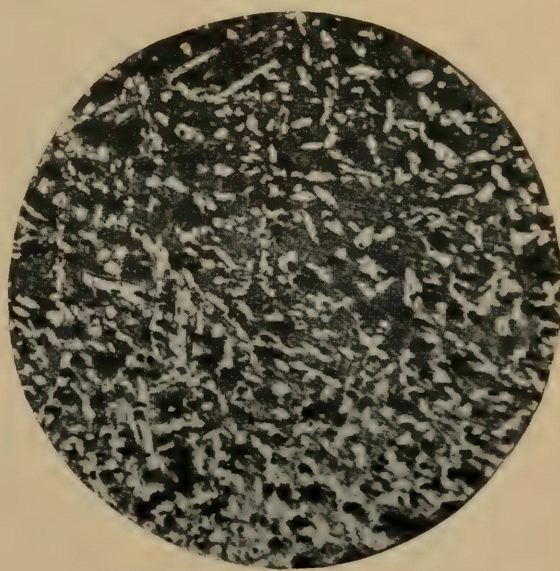


FIG. 14. Cu, 55%; Zn, 40%; Pb, 5%; 200 d.

that the metal "sweats," according to a mill expression, liquid lead being expelled.

It is, however, possible, with the necessary care, to roll brass containing as much as 7 per cent of lead. With more lead, that metal collects at the bottom of the molds when the brass is cast, and during the rolling it is expelled in great abundance.

In brass containing 70 per cent of copper, and as little as 1.5 per cent lead, lead globules are formed as shown in Fig. 15.

* This coloration might be attributed to the small amount of copper, for it is known that with 70% copper, brass has a greenish yellow color; with 58 to 50% copper it becomes yellow; while with about 45% copper it is red, and with less copper it becomes silver white.

Manufacture. — The lead is added when the crucible is still in the furnace and a short while before casting. The alloy is carefully stirred. Lead, as already stated, facilitates the hot forging of the alloy.

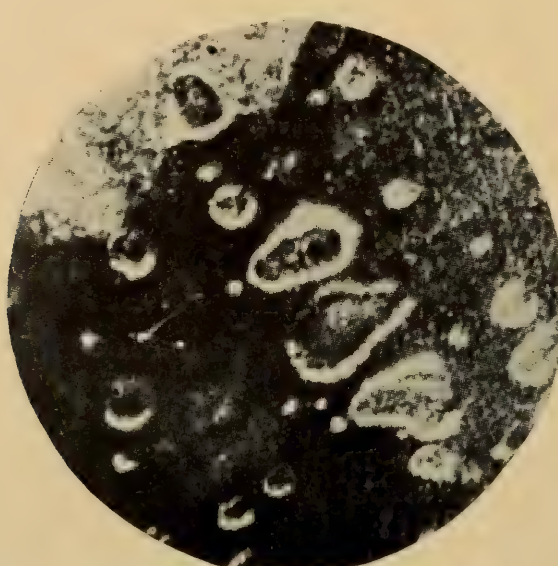


FIG. 15. Cu, 67%; Zn, 30%; Pb, 3%; 200 d.

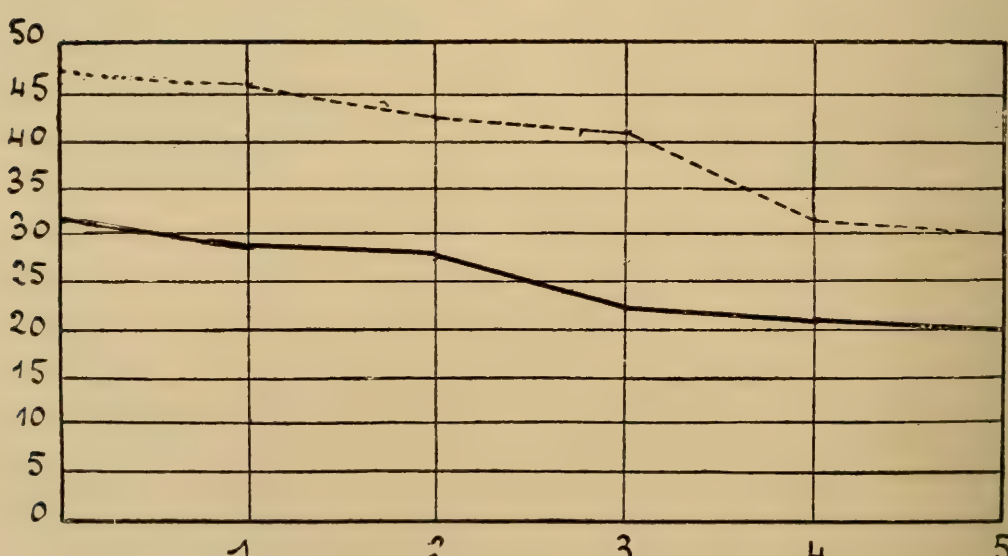


DIAGRAM 2. Lead Brass. Forged and Annealed Bars

Properties. — Diagrams 2 and 3 illustrate the results obtained in one experiment. The following conclusions may be drawn regarding the influence of lead: (1) It gradually decreases

the tenacity of brasses containing 60 to 70 per cent copper. (2) It affects similarly the elastic limit. (3) It decreases materially the elongation and reduction of area. (4) It causes brittleness. (5) It does not greatly affect the hardness of the alloy, at least as defined by the Brinell test.

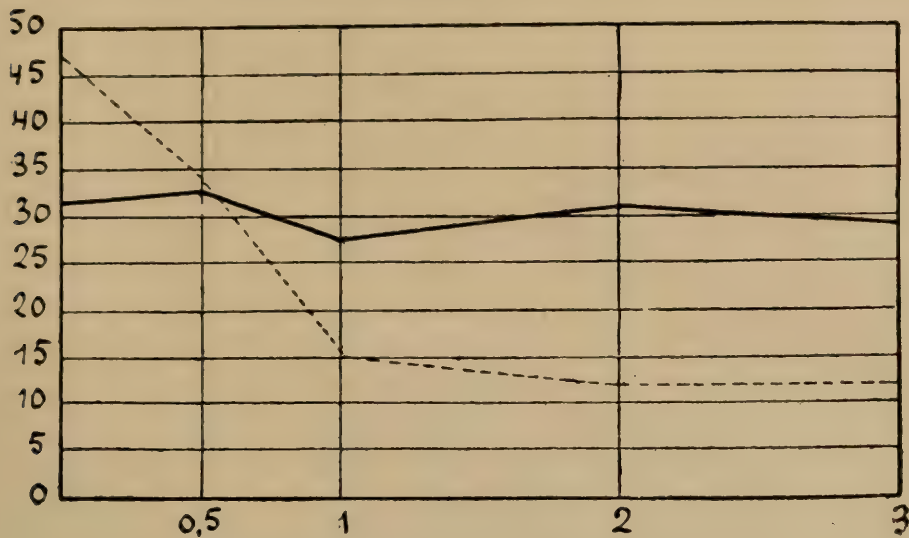


DIAGRAM 3. Lead Brass. Cast Bars

To sum up, lead is decidedly detrimental, especially when present in excess of 3 per cent.

Uses. — Because of the influence of lead, brass containing that metal can only be employed for the manufacture of appliances requiring but a small amount of work. Its beneficial effect is to facilitate the working of the alloy.

(*To be continued*)

THE CONSTITUTION OF IRON-CARBON ALLOYS*

STABLE AND METASTABLE EQUILIBRIA IN IRON-CARBON ALLOYS

By E. HEYN, Charlottenburg

Translated for The Iron and Steel Magazine by MILES S. SHERRILL, Massachusetts Institute of Technology

(*Continued from page 417*)

IT has already been shown that even relatively slightly accelerated cooling exerts an influence on the appearance of the pearlite, that is, gives rise to transition conditions. From this is to be drawn the conclusion that the velocity of the quenching must have a very material effect on the intermediate conditions retained in unstable equilibrium between the mixed crystals M and the pearlite. The degree of instability is, of course, less, the nearer the intermediate product stands to the pearlite, and larger, the more it approaches the crystals M. It is apparent that all of these conditions deserve the most careful consideration in the hardening of steels, and will lead to more scientific operations for these processes than those which have been used up to the present time.

As a beginning let us assume a uniform fall of temperature within the critical temperature zone EB_e (or $E'B_e'$) occasioned by the quenching; that is to say, let the time $\triangle t$ required to pass through a definite range of temperature $\triangle T$ be always the same; or, let $\frac{\triangle T}{\triangle t}$ be constant. Further, let us assume, for simplicity, that all alloys be quenched at a temperature which lies on the line OVPQ (Fig. 1).† Then, if the critical range from T to 700° be equal to i, the time required to pass through this range t_i is greatest in the case of those alloys which lie furthest to the right and left from the eutectic point P.

With the eutectic alloy containing 0.95 per cent carbon, t_i has its minimum value.

According to this, it is to be expected that with those alloys lying furthest to the right or left of P the supercooling

* "Zeitsch. f. Elektro-Chemie," Vol. X (1904), 491.

† For other cases the corresponding phenomena can be derived analogously.

will be most incomplete; only a partial supercooling will occur. The crystals M will be decomposed (devitrified)* into two constituents *f* and *m*, of which *f* will be poorer, and *m* richer in carbon than M. By slowly cooling from T to just above 700°, so as to allow the attainment of stable equilibrium, *f* would change to ferrite (C = O) and *m* to $M_{0.95}$ (C = 0.95 per cent). These percentages of carbon for *f* and *m* are to be considered as extreme limiting values which they more or less closely approach according to the value of t_i. With steels containing more than 0.95 per cent carbon similar phenomena will occur on quenching; M will decompose into *m* with less carbon, and into *c* with more carbon than M. For stable equilibrium just above 700°, as a result of slow cooling, the extreme limiting value for *c* would be 6.67 per cent carbon, corresponding to pure cementite, and for *m*, 0.95 per cent carbon, corresponding to $M_{0.95}$.

In the case of the eutectic alloy P, with 0.95 per cent carbon, the decomposition of M will not take place at all on account of the minimum time t_i, or the two components of the decomposition *f* and *m* will differ only quite immaterially from each other and from M. The greater the value t_i, the more *f* and *m*, or, as the case may be, *m* and *c*, can deviate from each other; that is, the nearer will the equilibrium approach that which is stable just above 700°.

According to the orginal nomenclature of Osmond, the mixed crystals M in quenched iron-carbon alloys which have more or less decomposed into *f* and *m*, or, as the case may be, *m* and *c*, have received the name "martensite," in honor of Professor Martens. It can be easily recognized and determined under the microscope. In the photograph (Fig. 12) a typical martensite is shown.† It is built up of fine needles crossing each other, which have different powers of resisting the action of a solution of hydrochloric acid in alcohol (1:100). The above name I believe in retaining because it seems to me to be practical, and remains uninfluenced by differences of opinion yet to be settled. Later Osmond deviated from this nomen-

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* The expression "devitrification" is, of course, not literal here, but is used metaphorically.

† By printing, the characteristics have unfortunately been considerably obliterated.

clature. In those martensites consisting of *c* and *m* he designated the constituent *m* as martensite, and gave to the constituent *c* the new name "austenite" in honor of that worthy investigator Roberts-Austen. In alloys poor in carbon where it is never possible to obtain by quenching non-decomposed crystals M, a special name might, with the same right, be given to the constituent *f*, while *m* would retain the name martensite. The separation into *f* and *m* is, moreover, in these low carbon alloys, at least, just as marked as the decomposition into *c* and *m* in high carbon steels. In spite of this, no one has wasted any thought concerning *f*, while the austenite has led to many and, in some cases, very theoretical discussions.

FIG. 12. Tool Steel. Hardened. Magnified 270 diam.

FIG. 13. Steel containing 0.17% C. Quenched at 1100° C. in water. Magnified 1,650 diam.

Photograph 13 corresponds to an iron-carbon alloy containing 0.17 per cent C (Si = 0.02, Mn = 0.02, P = trace and S = 0.03), which was quenched at 1100° in water. The photograph was taken after etching with a solution of hydrochloric acid in alcohol (1 : 100). If complete supercooling had occurred, the structure would have consisted entirely of homogeneous mixed crystals $M_{0.17}$. A very distinct decomposition in two substances is, however, to be noted; one is needlelike and corresponds to the high carbon *m*, the second, not needlelike, exhibits similarity to ferrite, and corresponds to the decomposition product *f*.

Photograph 14, representing an alloy with 0.21 per cent carbon (Si = 0.31, Mn = 0.63, P = 0.115 and S = 0.057) which was quenched at 900°, shows distinct decomposition; depressed veins and needles *f* in a matrix *m*.

Photograph 15 represents a high carbon alloy with 1.3 per cent carbon which was quenched from 1180° in water at 1°. The photograph was taken after etching with a solution of hydrochloric acid in water (1:100), whereby the sample was made the positive electrode for a half minute with a current of 0.2 ampere. The decomposition is very marked. The dark constituent corresponds to the decomposition product *m*, the

FIG. 14. Steel containing 0.21% C. Quenched at 900° C. Magnified 1,650 diam.

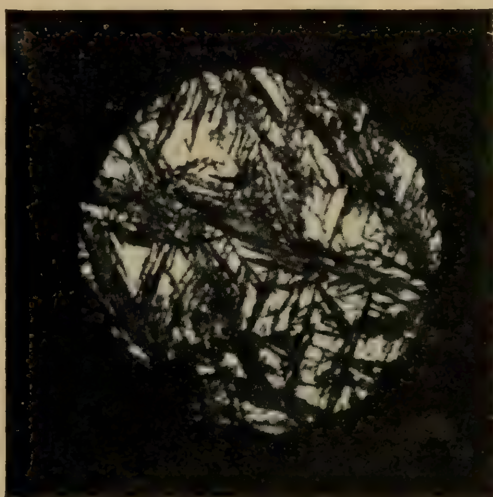

FIG. 15. Steel containing 1.3% C. Quenched at 1180° C. in water at 1°. Magnified 365 diam.

light one to the decomposition product *c* (according to Osmond's nomenclature *m* would be martensite, and *c* austenite).

Whether the special designation "austenite" and the hypotheses concerning its formation are justifiable, I prefer for the present to leave undecided. My own observations concerning the austenite differ from those of Osmond. According to Osmond, austenite is characterized by the fact that it remains uncolored when the sample is made the positive pole in a dilute aqueous hydrochloric acid solution, while martensite becomes colored. Austenite is said to be softer than the colored structural constituent. With the austenites which I have examined

this was just reversed; they were all harder than the martensites which were associated with them. Neither do the conditions given by Osmond under which only the austenite should form agree with my observations, which seem to indicate that the explanation of the austenite is of a simpler nature. With steels containing more than 0.95 per cent carbon, decomposition of the crystals M into *m* and *c* occurs; presumably *c* corresponds to Osmond's austenite, and *m* to his martensite. According to my designation the whole mixture $m + c$ is to be regarded as martensite. It remains for further investigations to clear up this matter, and to decide whether austenite (according to Osmond) is to be really regarded as a separate phase, or whether it only corresponds to an unstable transition constituent.

It follows from the preceding considerations that martensite, under otherwise equal conditions, must, on account of the decomposition into *f* and *m*, or into *c* and *m*, show a coarser structure, the further its carbon content lies from 0.95 per cent carbon; that, however, on approaching this value it should show only a slight decomposition. This is actually confirmed by experience.

As a reliable means of etching, for the investigation of quenched iron-carbon alloys, I have become familiar with a reagent which has already been used by Professor Martens, a solution made up of 1 ccm. of concentrated aqueous hydrochloric acid and 100 cc. of absolute alcohol. It gives excellent results if the precaution is taken of placing the polished face after etching into absolute alcohol and not into water. Treated in this way, martensite, even after etching for half an hour or more, appears colorless, ferrite under strong magnification likewise colorless, and, as a result of figures caused by the etching, roughened. Cementite is not attacked at all. Only with very low carbon steels is a slight yellow coloring present. In quenched steels, however, there occurs, as a rule, besides these weakly or quite colorless structural constituents, one which is quite darkly colored. The latter was called by Osmond troostite, and was characterized as a transition constituent from martensite to pearlite. This has been fully confirmed by my observations, which show that, according to the rapidity of the quenching, troostite or martensite is formed.

With a somewhat diminished quenching velocity principally troostite is formed; with increased velocity, on the other hand, martensite. The difference in velocity necessary for this distinction appears to be but slight. This may be well seen from the following example:

A steel containing 0.5 per cent carbon and very small amounts of other substances was quenched in the form of two small plates *a* and *b* from 710° in water at 18°. The two plates *a* and *b* were 6 mm. square and had a thickness of about 3 mm. The plate *a* had a groove for the insertion of the junction of a thermo-element, which was clamped between *a* and *b*. The plates *a* and *b* were bound together by means of iron wire. The surface of the sample *b* was cleaned, polished and etched. The places rich in troostite appear dark even to the naked eye, while those poor in troostite appear light. Enrichment of the troostite in the form of a cross can be easily recognized. At the corners the heat abstraction was strongest, and therefore the quenching the most severe; there, only the martensite formed. Towards the middle of the edges the quenching was less severe and therefore formation of troostite occurred; in the middle of the sample the troostite formation is strongest. With all iron-carbon alloys investigated by me similar phenomena were observed, although the troostite formation did not occur equally developed in all of them. Since the dimensions of the sample affect the heat abstraction at different places, they influence materially, of course, the formation of troostite. In relatively large steel rods a regular increase of troostite towards the middle of the cross section is to be noticed.

In spite of their very different optical characteristics, martensite and troostite are in their metallographic relations very much alike. On annealing, both change to the same structural constituent, sorbite, and are then no longer distinguishable from one another. Scarcely any difference in their hardness is to be noted; they appear after relief polishing on the same level.

My observations have shown that with one and the same steel under otherwise the same conditions, the quantity of troostite decreases when the quenching temperature is raised. Addition of a relatively small amount of manganese also exerts a powerful influence. Manganese, even when present in the

small amounts which are ordinarily found in commercial steels, hinders the formation of the troostite. This might be easily explained by saying that manganese increases the tendency towards supercooling, that is, works against the "devitrification."

I should like to mention still another striking phenomenon. A low carbon steel quenched from a temperature just above 700° would, when completely cooled, be expected to consist of ferrite (A) and martensite (C) with almost the eutectic carbon content 0.95 per cent C. (Compare Fig. 17.) Since the critical interval BB_e is very small, the mixed crystals M_c have no, or only

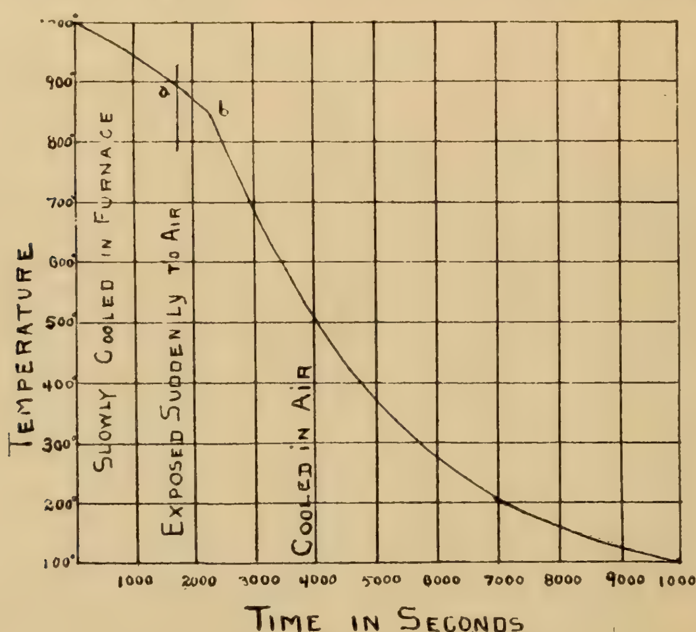

Fig. 16

a very slight, opportunity to decompose; this is actually so, but there results generally but little of the nondecomposed martensite, in predominating amounts, however, troostite. Indeed, the smaller the manganese content and the nearer the temperature B lies to B_e, the more troostite is obtained. The experiments which support these assertions were all carried out as follows: The samples were heated to about 1100°, cooled slowly in a furnace to B, and then at B quenched quickly in water. In order to explain this appearance of the troostite under the conditions just mentioned, cooling experiments were made with a clay cylinder 40 mm. in diameter and 50 mm. high. The cylinder

after reaching 1000° was cooled slowly in the furnace to 900° and then, with a thermo-element fastened tightly to the interior, exposed suddenly to the air and allowed to cool. The cooling curve is given in Fig. 16. It shows that a rapid fall in temperature of the sample does not occur immediately on exposure to the air, but that at first a retardation is to be noticed between *a* and *b*. Similar quenching experiments with metals are, of course, not applicable because the indicator of the galvanometer cannot follow the changes in temperature which occur. There is, however, no reason to doubt that on quenching an iron-carbon alloy from a quenching temperature *a*, likewise a retardation *ab*, as in Fig. 16, occurs, and that the real rapid fall takes place only from *b* on. Considering the extreme sensitiveness of the mixed crystals M_c to form troostite and not martensite when the quenching is not too severe, it is to be expected that

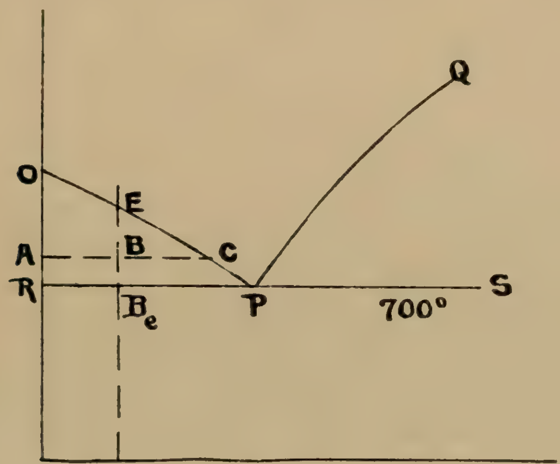

FIG. 17

during the period *ab* principally troostite will form. If the eutectic temperature lies between *a* and *b*, then the mixed crystals M_c change over almost entirely into troostite, and the structure in the chosen case would be expected to be made up of ferrite and troostite in the ratio

$$\frac{\text{Ferrite}}{\text{Troostite}} = \frac{\text{BC}}{\text{BA}}$$

(Compare Fig. 17.) If, on the other hand, the eutectic temperature, 700°, lies below *b*, then between *a* and *b* would be expected mainly the change of the mixed crystals M_c to troostite, and between *b* and 700° the change of M_c to martensite. The structure

would then consist of ferrite surrounded by troostite, and inside of the troostite, martensite. It constitutes an alloy with 0.20 per cent carbon (Si = 0.04, Mn = 0.04, P = trace, S = 0.03) which has been quenched at 730°. Imbedded in the bright matrix of ferrite lie little islands, which are partly colored black (troostite) and partly light gray (martensite). The quantity of the troostite predominates over that of the martensite. The higher the quenching temperature *a* lies, the more probable it is that *b* lies above 700°.

Since an iron-carbon alloy which has been quenched exists at ordinary room temperature in unstable equilibrium, there must lie within it a latent endeavor to approach the stable condition of equilibrium, that is, to decompose into the two phases ferrite and cementite. There is connected with this decomposition, however, a diffusion of the two phases over comparatively long distances, and against this diffusion there acts the frictional resistance which is large at these lower temperatures. On increasing the temperature, the frictional resistance must decrease to a certain extent, and it will therefore be possible for the alloy to approach to a certain degree the stable condition. This is the action which takes place on tempering hardened steels. This action begins even at the lower temperatures, and at 250° to 300° exerts marked influences. The same power of diffusing possessed at 700° or higher is, however, not to be expected at the lower temperatures. No change can take place, therefore, on the surfaces occupied by the ferrite or cementite, because here diffusion over large distances would be necessary. The martensite undergoes, however, a decided change; it changes into a substance which has received the name "sorbite" from Osmond, and which is extraordinarily closely related to troostite, indeed is possibly identical with it. Sorbite is presumably a mixture of substances similar to ferrite and cementite so intimate that it cannot be resolved even under the highest magnification. It is therefore to be regarded as an almost molecular mixture of the two substances. After annealing, martensite and troostite have the same appearance, they have both changed over into sorbite.

(*To be concluded*)

THE THERMO-CHEMISTRY OF IRON ORE REDUCTION AND STEEL MAKING *

IN THE ELECTRICAL FURNACE

By HORACE ALLEN, C. E.

OF the many applications of electricity to metallurgical purposes in the way of competing with the well-developed processes at present in vogue, probably the most striking is its employment in the commercial production of cast iron and steel. Recent developments have proved that electricity may be successfully employed in the manufacture of iron and steel in such a manner as to indicate that this method is likely to enter into the field of competition as regards certain classes of product at any rate.

When Mr. Albert Keller read his paper on "The Application of the Electric Furnace in Metallurgy" before the Iron and Steel Institute in May, 1903, the possibilities of electricity entering into competition with the usual methods of production of cast iron direct from its ores, and steel of such high class as that required for tools, was doubtless received with great incredulity. The rapid progress being made in this direction is, however, being forced upon our attention, and necessitates the consideration of the thermo-chemistry of the subject.

The chemical considerations entering into the reactions may remove the doubts which have occurred to the minds of those actively engaged in the production of iron and steel by the usual methods, and give good reasons explanatory of the possibilities in this direction. The object of this article is not so much to discuss the various methods at present being subjected to practical trial as so show the limits necessitated by the chemical reactions. To deal with the subject from a thermo-chemical point of view necessitates the employment of such factors as

1. The specific heat of the materials.
2. The heat of chemical combination.
3. The reactions occurring in melting or reduction.
4. The temperature attainable in the electric furnace.
5. The temperatures of the molten products, etc.
6. The latent heat of the products.

---

*" Cassier's Magazine," March, 1905.

TABLE OF SPECIFIC HEATS

Iron	0.11379	(Regnault)
Carbon	0.02411	,,
Magnetic oxide, Fe_3O_4	0.154	
Sesquioxide of iron, Fe_2O_3	0.171	
Cast iron	0.1124	(Bystrom)
Iron	0.10601 + 0.000014t ° C	(Tomlinson)
Steel	0.1217	
Carbon, graphite	0.1604	(Weber)
,, charcoal	0.1935	,,
,, coke	0.1571	
Slag	0.148	
Manganese	0.1217	(Regnault)
Silicon, crystalline	0.1697	(Weber)

HEAT OF CHEMICAL COMBINATION

For 1 lb. of substance in British Thermal Units.

Fe product,		Fe_3O_4	2,880
Fe	,,	Fe_2O_3	3,650
C	,,	CO_2	14,544
C	,,	CO	4,451
CO	,,	CO_2	4,350
Si	,,	SiO_2	14,094
Mn	,,	MnO_2	3,803
The Board of Trade unit			3,410

CHEMICAL REACTIONS IN THE PRODUCTION OF IRON AND STEEL

$$Fe_3O_4 + 4\,C = 3\,Fe + 4\,CO$$
$$Fe_2O_3 + 3\,C = 2\,Fe + 3\,CO$$
$$MnO_2 + 2\,C = Mn + 2\,CO$$

The temperature of the electric arc being about 5970° F., the temperatures resulting from the employment of the electric current can be made to range from comparatively low heats up to that of the simple arc. The temperature at the tuyères of the blast furnace will be about 5166° F.

The melting points of the various products are about as follows:

Pure iron	2,730 — 2,900° F.	(Pouillet)
Gray cast iron	2,910 — 3,450° F.	,,
White cast iron	2,530 — 2,730° F.	
Steel	3,272° F.	
Magnetic oxide	2,370° F.	

The latent heat of the substances may be taken as:

Cast iron	233	(Clement)
Slag	249	

In ordinary blast-furnace practice it requires the application of about 1 ton of coke to produce 1 ton of pig iron, in high furnaces, with heated air blast. If the thermal value of the coke be taken as 13,000 B. T. U. per pound, then each pound of pig iron requires the application of 13,000 B. T. U. to be provided in the form of coke.

To produce one ton of steel in a Siemens furnace requires the application of 7 cwt. of coal to the gas producers; this, at 13,000 B. T. U. per pound, is equivalent to 4,550 B. T. U. per pound of steel. As there is about 3 per cent loss in the process, the above figure should be increased to 4,690 B. T. U. to make the comparison on the basis of the iron employed.

When the product consists of an alloy of iron containing 20 per cent of manganese, the weight of fuel in the form of coke amounts to 26.5 cwt. per ton of product, which, at 13,000 B. T. U. per pound of coke, is equivalent to 17,225 B. T. U. per pound of product.

When the product of the blast furnace is ferro-manganese, then 41.4 cwt. of coke are required per ton of product, and, on the same basis as considered above, the equivalent per pound of ferro-manganese is 26,910 B. T. U.

Crucible steel manufacture requires from $2\frac{1}{2}$ to 3 tons of hard coke per ton of product, or from 32,500 to 39,000 B. T. U. per pound of steel.

Theoretically, 1 pound $\times$ 0.1217 $\times$ 3272° + 233 = 631 B. T. U.

Mr. J. E. Stead's figure for this is 718 B. T. U.*

Melting pig iron in large cupolas requires about $4\frac{1}{2}$ per cent of hard coke, by weight, or, per pound of iron melted, 580 B. T. U.

Theoretically, 1 pound $\times$ 0.1124 $\times$ 3000° + 233 = 570 B. T. U.

From this it appears that in melting iron in cupolas an efficiency of about 90 per cent is obtained.

Mr. Albert Keller referred to an electric furnace which was capable of producing 1 ton of cast iron by the expenditure of $\frac{1 \text{ kilowatt year}}{4}$ + 771.4 pounds of coke for the reduction of the ore, which, expressed in B. T. U., is,

* Discussion on Mr. Albert Keller's paper.

For electric smelting	7,467,900	= per pound 3,334
771.4 pounds of coke to CO_2	3,433,500	= per pound 1,532
Total B. T. U. to produce one ton	10,901,400	
Total B. T. U. to produce one pound		4,866

To compare this with blast furnace practice and coke at 16*s*. per ton:

In the blast furnace 1 pound of pig	= 0.085*d*.
Reduction in electric furnace coke at 16*s*. per ton.	
Electric current ¼*d*. per B. of T. unit per pound of pig	= 0.244
Coke for reduction per pound of pig iron	= 0.010
	0.254*d*.

The ratio of cost is thus 1 to 3.

Where there is a cheap and ample water supply, as Mr. Keller refers to, for an installation in Brazil, the B. of T. unit being estimated to cost 0.03*d*., the figures are,

Electric current at 0.03*d*. per unit per pound of pig	0.0293*d*.
Coke for reduction at 16*s*. per ton	0.010
	0.0393*d*.

This gives a ratio of 1 to 0.5.

However, it must be noticed that the cost of coke in Brazil comes to 48*s*. per ton, which would give,

Current	0.0293
Coke	0.03
	0.0593

in which case the balance is still in favor of the electric furnace.

In regard to the manufacture of steel by electric current, Mr. Keller states that about 0.1 kilowatt-year is necessary for melting and fining 1 ton of steel, by the fusion of scrap iron and steel.

To turn these figures to their equivalent in B. T. U., we have

0.1 KW-year = 2,728,000
or per pound of steel, 1,218 B. T. U.

As we have seen that, theoretically, 1 pound of steel requires for melting alone 631 B. T. U., the efficiency, without providing for the fining process, comes out as 52 per cent.

Comparing this with the figures given for crucible steel, we have

Per pound of steel by electric furnace .... 1,218 B. T. U.
Per pound of steel by crucibles and coke .... 32,500 B. T. U.

Again, taking coke at 16*s*. per ton, and bringing the cost per B. of T. unit to an equivalent rate, we have,

Coke for crucible steel per pound of steel .... 0.21*d*.
Equivalent value of B. of T. unit when the steel is produced electrically .... 0.59*d*.

or a little more than ½*d*., at which rate a large, suitably actuated and equipped generating station can readily supply it at a profit, even from steam.

Mr. Keller, referring to the electric steel furnace at Livet,* gives the figures at 2,800 KW-years per ton of steel, equal to 4,262 B. T. U. per pound of steel, or nearly four times the former figures; but this may refer to the combined process of electric blast furnace and electric fining furnace.

Mr. G. Ritchie (Glasgow), in describing the working of a Kjellin furnace at Gysinge, Sweden, in the correspondence on Mr. Keller's paper, gave some interesting particulars. The furnace is of the "transformer" type, consisting of a circular brick structure with a primary coil placed in the center; around the primary coil, but in the brickwork, an annular groove, or chamber, forms the receptacle for the charge to be melted, constituting the secondary coil. The current is thus induced in the charge itself, and transformed from 3,000 volts to 7 volts, there being no electrodes.

The power used amounts to the equivalent of 1,449 to 1,980 B. T. U. per pound of steel, or, compared with the figures given earlier in this article, the

efficiency being $\frac{631}{1{,}449} = 43$ per cent to $\frac{631}{1{,}980} = 32$ per cent, without taking the fining period into consideration.

However, the steel resulting is of high class, and has a fair sale for all classes of work, including tools, dies, scythes, surgical

* Mr. J. E. Stead has seen 1,873.4 pounds of steel, in the form of turnings, melted in the electric furnace at Livet in two hours, at the rate of 600 KW-hours per ton, which is equivalent to 913 B. T. U. per pound of steel, as compared with 631 B. T. U., the theoretical amount before stated, the efficiency being, therefore, about 70 per cent. In this case the steel contained only 0.16 per cent carbon.

instruments, etc., and, therefore, the efficiency of the process should be compared with the crucible steel process.

Crucible steel by coke per pound	32,500 B. T. U.
Electric steel per pound	1,449 B. T. U.

In the February, 1904, number of "Electrochemical Industry," Mr. Marcus Ruthenberg, in an article on "The Smelting of Iron Ores and the Production of Steel in the Electric Furnace," refers to the following developments in this direction:

Describing a plant situated at Niagara Falls, he says the operator, in discussing the smelting of iron ores electrically proved, theoretically and practically, that it required the continuous expenditure of 200 horse-power to produce one ton of metallic iron in twenty-four hours, or 4,800 horse-power hours. Stasano, in Italy, claims to smelt a ton of finished product with 3,000 horse-power hours.

De Laval, in Sweden, required 3,500 horse-power hours, and Rossi, at Niagara Falls, 4,800 horse-power hours, and plants in France give results not differing much from those above mentioned.

The respective efficiency of these operators may approximately be stated as follows, compared with the figures following for magnetic oxide:

Rossi	per pound	= 5,454	B. T. U.	efficiency nearly	60%
De Laval	,,	= 3,976	,, ,,	,,	81
Stasano	,,	= 3,408	,, ,,	,,	92
Blast furnace		= 13,000	,, ,,	,,	25

This comparison is only approximate. Mr. Ruthenberg at this stage gave the result of his furnace as only requiring 500 KW-hours per ton of metal produced, or 716 B. T. U. per pound of metal.

The efficiency in this case would amount to about 51 per cent compared with the smelting of Fe_3O_4. He also states that the coke required in the blast furnace for the chemical action of reduction was but a little over 300 pounds per ton of metal, or 0.134 pounds of carbon per pound of iron produced, or 533 B. T. U. per pound of metal produced.

However, in connection with this it is necessary to compare the method adopted by Mr. Ruthenberg with that of previous operators. With earlier workers, the practice was to melt the

ore and maintain it molten by making the molten mass the resistance to the electric current, which, being low, necessitated a great expenditure of energy.

In the Ruthenberg furnace the only energy required is that necessary to bring the magnetic oxide to the molten condition, when the operation of reduction by carbon, or carbonic oxide, will proceed without the further application of external heat.

The furnace consists of two revolving barrels or rolls of bronze, water cooled, and placed over the poles by a horizontal horseshoe magnet.

The ores employed may be in a state of fine division, such as would not be available for use in the blast furnace; in fact, the finer, the better, provided that they are rich in quality, thus allowing of a previous magnetic concentration. It will be noticed that the rolls, which are covered with carbon, form the poles of the melting circuit, and as fast as the ore is fused, losing, as it does, its magnetic property, it falls into a receptacle below, where the final reduction is effected by carbon or carbonic oxide.

The Stasano method consists of reducing the metal direct from the ore by carbon, by the aid of an electric arc formed above the mass of mixed ore and carbon, a current of 2,000 ampères at 170 volts being necessary.

The ore employed consisting of almost pure peroxide of iron, the chemical reaction is represented by the equation,

$$\begin{array}{cccc} Fe_2O_3 & + 3\,C & = 2\,Fe & + 3\,CO \\ (56 \times 2) + (16 \times 3) & & & \\ 112 + 48 & 12 \times 3 & 56 \times 2 & 28 \times 3 \\ \hline 160 & 36 & 112 & 84 \end{array}$$

The heat to be supplied in reducing the ferric oxide being 3,650 per pound of iron, 112 pounds = 408,800 B. T. U One pound of carbon combining with oxygen to form carbonic oxide liberates 4,451 B. T. U., so that the 36 pounds of carbon would give 160,236 B. T. U., showing that the reaction requires the application of heat from some external source to the amount of 348,564 B. T. U. per 112 pounds.

However, it will be noticed that CO is given off to the extent of 84 pounds, which, on further combustion, give 84 × 4,350 = 365,400 B. T. U., which, if applied to develop heat in the operation, shows that the quantity of electric current necessary

would be greatly reduced, the heat balance of the reaction being theoretically almost perfect.

At one of the recent meetings of the American Electrochemical Society, Mr. Marcus Ruthenberg gave further particulars of results obtained by his furnace. Instead of requiring 500 KW-hours of energy to produce a ton of iron, he has succeeded in doing this with about 250 KW-hours, so that it will be interesting to consider the thermo-chemistry of the operation.

The material employed being magnetic oxide, almost pure, the application of the electric current has only to bring it to the point of fusion. Taking the fusing temperature as 2370° F., and the specific heat as 0.154, the thermal requirements are, 1 pound × 0.154 × 2370° = 365 B. T. U.

To reduce the magnetic oxide to metallic iron and oxygen requires the further application of heat to the extent of 2,880 B. T. U. per pound of iron. If carbon is employed for the reduction, the chemical equation is,

$$\underbrace{\underset{168}{\underline{\overset{Fe_3}{56 \times 3}}} \quad \underset{64}{\underline{\overset{O_4}{16 \times 4}}}}_{232} + \underset{48}{\underline{\overset{4\,C}{12 \times 4}}} = 3\,Fe + \underbrace{\underset{28 \times 4}{\underline{\overset{4\,CO}{12.16}}}}_{112}$$

168 × 2,880 = 483,840, or, per pound, 2,880 B. T. U.

The carbon combining with O to form CO = 48 × 4,451 = 213,648 B. T. U., or, per pound of iron, 1,271 B. T. U., showing in this case that unless the CO formed is applied to make up the deficiency, this must be derived from the electric current.

The CO would be capable of developing 112 × 4,350 = 487,200 B. T. U., or, per pound of iron, 2,900 B. T. U., which more than provide for the heat requirements.

However, if the reduction is to be by CO gas, the equation becomes,

$$\underset{168}{\underline{\overset{Fe_3}{56 \times 3}}} \quad \underset{64}{\underline{\overset{O_4}{16 \times 4}}} + \underbrace{\underset{28 \times 4}{\underline{\overset{4\,CO}{12.16}}}}_{112} = 3\,Fe + 4\,CO_2$$

In this case 112 pounds of CO will supply 112 × 4,350 = 487,200 B. T. U., or, per pound of iron, 2,900 B. T. U., or suffi-

cient heat, if loss could be prevented, to carry on the reaction continuously.

In Heroult's electric furnace for the production of steel from scrap iron as carried out in France and Sweden, the current passes from two vertical electrodes through the slag which covers the metal. With one furnace working 5-ton heats, the product is 15 tons in twenty-four hours, using 600 horse-power produced by a blast furnace gas engine. The quality of the steel is that of high-grade tool steel. This works out at 716.2 KW-H. per ton of steel, or about 2,444,240 B. T. U. per ton = 1,090 B. T. U. per pound of steel.

Crucible steel by coke, per pound	32,500 B. T. U.
,, ,, ,, Heroult furnace	1,090 B. T. U.

The latter figure is only slightly higher than that required by theory, while the former is about 42 times that absolutely necessary when most effectively applied.

A study of the thermo-chemistry of the production of iron and steel by means of the electric current shows that when carried out on a system as nearly as possible in accordance with that required by theory, the capabilities of profitable application only require scientific treatment to prevent an excessive charge for electric current from turning the scale between profit and loss, even in the field of the blast furnace.

The calculations given are in the theoretical examples only approximate, but they will be of service to those who wish to consider the possibilities in the direction of the employment of the electric current as a factor in the manufacture of iron and steel.

METHOD OF MAKING TESTS ON METALS*

By Dr. A. GRADENWITZ

IN a recent communication to the Société d'Encouragement pour l'Industrie Nationale, M. Guillery describes what may be called a novel method for carrying out mechanical tests on metals. The process in question, which is being brought out by the Société Française de Constructions Mécaniques of Denian, France, is remarkable for its simplicity, this being a particularly valuable feature, as the more easily an investigation is performed the more frequently will manufacturers undertake a test of their products.

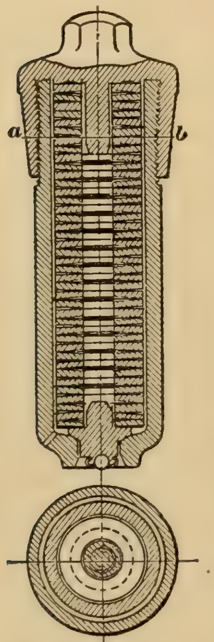

FIG. 1. Portable Apparatus for testing the hardness of metals

Though in some cases chemical and microscopical analysis will prove a valuable means of ascertaining the condition of a given metal, mechanical methods are to be applied in the first place, and as pointed out by M. Guillery, an efficient test should not only give accurate information as to the properties of the metal, but these data should be maintained in an unmistakable shape, that is quite independent of the personal opinion of the experimenter. From experiments carried out by the Société Française it is inferred that in the case of the metals generally used in practice, it is sufficient to investigate the hardness and brittleness, while the elastic limit is interesting only in certain cases and in the first place for special steel.

The outfit designed by M. Guillery is based on the penetration of balls submitted to a constant pressure on the surface of the metal. This will give the elastic strength, while the elastic limit is determined by means of the indentation of a polished surface of the metal, and for the brittleness, the flexion of notched bars under impact is relied upon.

According to actual practice, hardness is generally determined by testing the tensile strength, while a number of addi-

* "The Iron Trade Review," April 6, 1905.

tional tests relating to the elongation, bending, impact, etc., are frequently required. All of these tests are, however, insufficient by themselves to give any positive indication, and can guide the experimenter only in some way or other. Hardness as determined by tensile tests is a rather imperfect definition of this property, as the effect of contraction which makes itself felt at the moment of breaking is not taken into account. There is further a marked difference in the determination of tensile

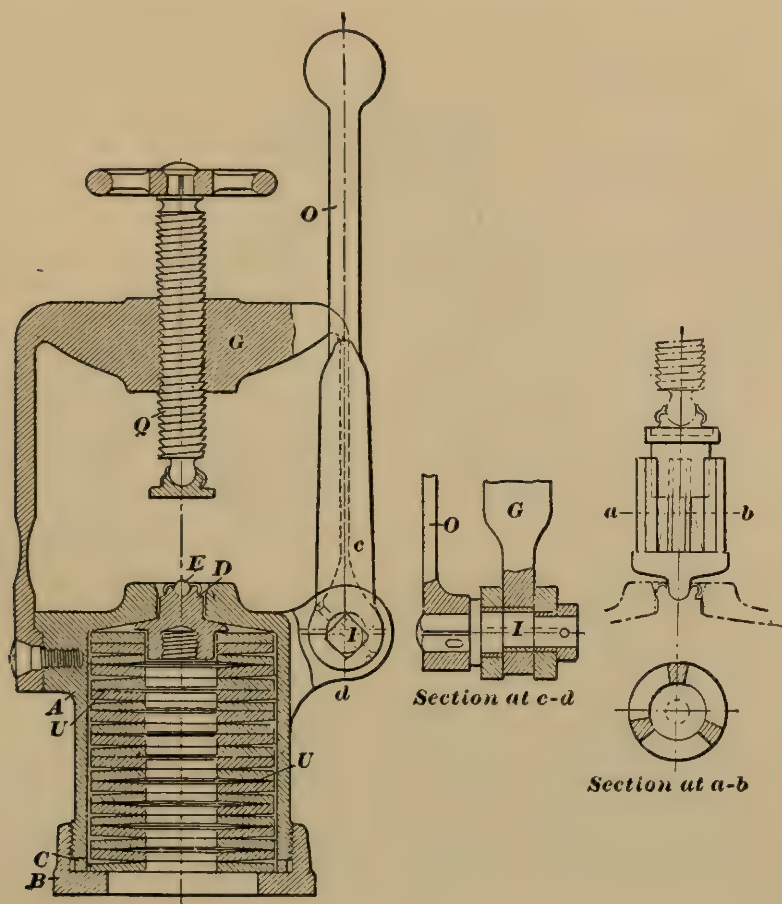

FIG. 2. The Precision Apparatus

resistance, according to the dimensions, shape, etc., of the test bars.

Tests on the penetration of balls are, on the contrary, truly characteristic of the hardness of a metal, giving as they do a homogeneous result, independently of any factors controlling the behavior of tensile strength. This process suggested by Mr. Brinell has a further advantage in that the only necessary

preparation is a rough polishing of some square centimeters of the surface of the sample, and a very valuable feature is the fact that tests instead of being limited to separate samples can be applied immediately to the piece concerned, in as many places as desired.

The determination of brittleness by the impact of notched bars is no doubt the most perfect process, being based on the determination of the work absorbed by the fracture. As regards

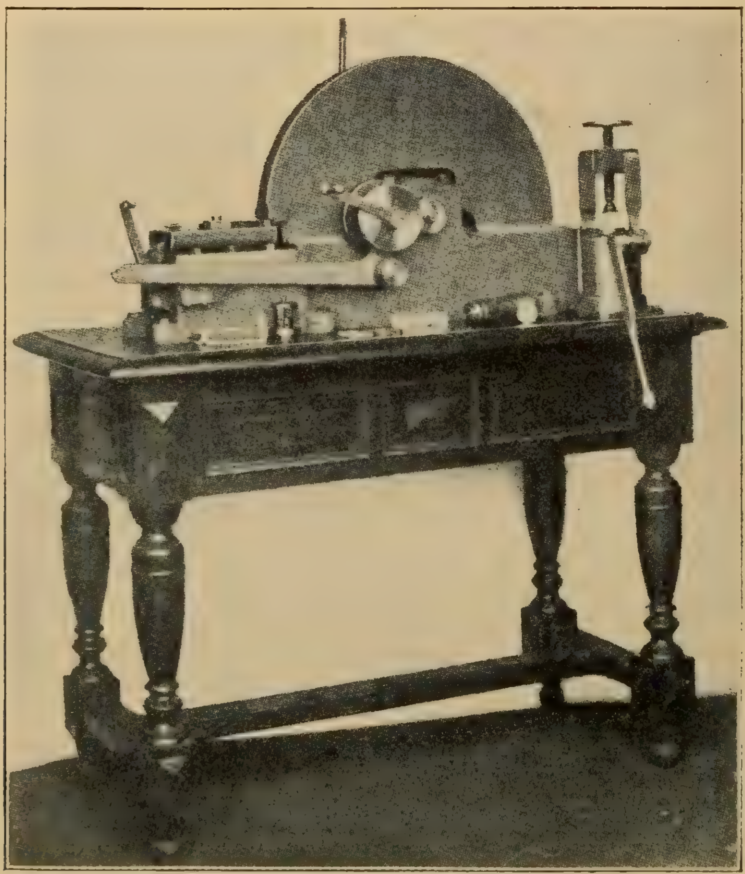

Fig. 3. Machine for Testing Fragility

the shape of the notches nothing definite need be stated and any desired form can be adopted in connection with the apparatus described by M. Guillery. Square test bars, 10 sq. mm. (.155 square inch) in cross section, with notches 2 mm. (.0787 inch) deep, are, however, recommended. The metal is indented by a ball pressed against its surface by means of Belleville disks under a given compression. Two types of apparatus have been

designed, one of which, being portable, enables any error of magnitude to be detected very rapidly, without, however, affording a sufficient means of checking the investigation of the metal. The other apparatus is an instrument of precision, which, while not being carried about as easily, does not either require any considerable amount of space. This latter apparatus is a very convenient outfit for tests on delivery and for research work.

The portable apparatus shown in Fig. 1 is designed for balls 5 mm. (.197 inch) in diameter. It is fitted with a head, to which a blow is applied, so as to give the pressure required (750 kg. or 1,650 pounds) without requiring any resting point. The excess of live force is absorbed by a circular stop, striking the test piece as soon as the load required has been obtained. A similar apparatus has been constructed for balls 10 mm. (.394 inch) in diameter with loads of about 3,000 kg. (6,600 pounds). This apparatus seems to be especially adapted for measuring the hardness of metal raised to fairly high temperatures.

The precision apparatus seen in Fig. 2 is designed for a statical pressure. It comprises a cylindrical steel box A screwed on a foundation socket B containing the Belleville disks U and a regulating packing disk C. The pressure of the disk is transmitted to the ball E by means of a support D. On the top there is a lever press serving to compress the sample on the ball until the load being sufficient the disks will collapse and the ball escape. This press consists of a stirrup G, fitted with a regulating screw Q and which serves to transmit the strain; as soon as contact is produced the tightening of the screw has to be discontinued. One of the ends of the stirrup G is connected to an eccentric axle I, driven by the lever O. The eccentricity is 1.5 mm. (.059 inch), so that by moving the lever through 180 degrees the sample is indented by that amount. Calibration is carried out, as in the case of a tensile testing machine, by means of a metal of known hardness. The apparatus using 10 mm. (.394 inch) balls is adjusted so as to make an impression of 7 mm. (.276 inch) in the rings. The bronze used at the mint for medals seems to give the most reliable results for calibration purposes. Comparative tests have been made on the figures given by tensile testing machines on one hand and by the present apparatus on the other. Up to 64 kg. the test pieces were made of annealed

steel of increasing hardness, while the last two are of tempered spring steel. The diameter of the imprints were measured by means of the Le Chatelier glass gauge, allowing of 1-10 mm. (4-1000 inch) being safely estimated with the naked eye. (The gauge here mentioned is probably a strip of glass ruled with two slightly converging lines. These are graduated to correspond with the distance the two lines are separated at any point. The strip being placed over any indentation or whatever is to be measured and the position of the glass adjusted until the object just bridges the interval spaced by the graduated lines, the diameter may be read off from the scale.)

The apparatus just described is without any previous alteration immediately suitable for ascertaining the elastic limit, it being sufficient to insert in a threaded link, located under the screw of the apparatus, frustums of polished cones, subjecting them to a maximum constant load, when the elastic limit is inferred from the ratio of the deformed cross section with the load.

The apparatus for determining brittleness (Fig. 3) utilizes a flywheel, which on being started at a convenient speed produces the fracture of the test bar. The resulting variation of live force is shown by the diminution in speed through a direct reading. A steel flywheel B (Fig. 4), being perfectly balanced, carries on its rim the knife edge that breaks the sample. The axle of the flywheel rests in two ball bearings, and at the instant of impact, it is borne on surfaces of ample area. The flywheel is regulated either mechanically or by hand to a speed such that the energy stored in the mass will be greater than that which in all cases is required to break the bar, and the speed of impact equal to that adopted in the brittleness test, that is corresponding to a free fall through 4 mm. (.157 inch). A cylindrical clutch, the movable element of which is mounted on the lever, serves to regulate the drive. This lever, being generally hooked to the frame, is made to engage the clutch on being released, when the flywheel begins gradually turning round up to the normal speed either under the action of the hand on a crank or in virtue of a rope transmission acting on the grooved pulley. The notched bar is placed between bearings on a sliding anvil. This anvil, which is of cast steel, carries a plate of hardened steel turned towards the blow; a spring of sufficient strength always tends

to move the anvil towards the wheel, that is, into the position where it will receive a blow. The mechanism locating the test piece under the knife edge in due season is a cam fixed on a rod, controlling it with a rotary movement, but traversing it freely in the direction of the axis. This rod terminates in a latch worked by a spring, which tends to keep the cam gear in and places the lever in front of the operator. When by the aid of the lever placed in front of the apparatus the anvil is pulled towards the operator, the spring throws the cam into gear and the latch

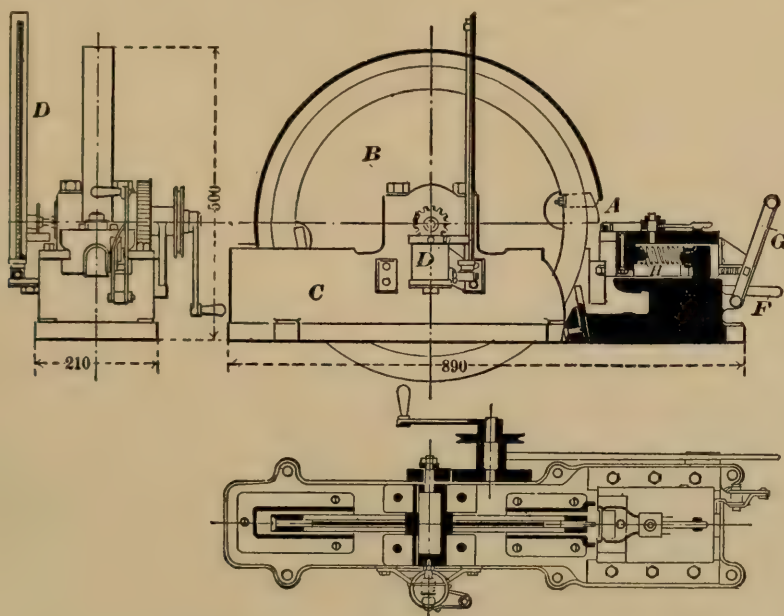

FIG. 4. Elevations and Plan of the Testing Machine

becomes horizontal. When the lever is pushed, the rod is displaced and the latch receives a blow from the knife edge, which throws the cam out of gear and leaves the anvil to the influence of the spring, this action being instantaneous. After the knife edge has made one complete revolution it strikes the test bar.

The speed and the work absorbed are given at any moment by a tachometer, consisting of a small centrifugal pump on a vertical axis. This is fitted with a graduated water level gauge. A safety mechanism renders it impossible to insert the test bar when the anvil is out of gear. The flywheel is covered by an iron case, protecting it against the risk of striking any projection.

THE BEST METAL FOR RAILS *

By P. H. DUDLEY

WHILE it is true generally as a statement that the rails which have a fine texture best resist the surface wear due to the rolling loads, photo-micrographs do not disclose the uniformity of structure some have expected. The proper structure for rails is simple, until an investigation is undertaken, then they are found intricate, with complex ramifications.

As a result of American experience the following may be given as the best metal to use for rails:

	75-pound	80-pound	90-pound	100-pound
Carbon	.45 to .55	.50 to .60	.53 to .63	.55 to .65
Silicon	.15 to .20	.15 to .20	.15 to .20	.15 to .20
Manganese	1.00 to 1.20	1.00 to 1.20	1.10 to 1.30	1.10 to 1.30
Sulphur not to exceed .	.08	.08	.08	.08
Phosphorus not to exceed	.09	.09	.09	.09

Out of 46 American railways 23 favor high carbon steel. Only 5 companies have reported a preference for rails of .40 to .50 in carbon, for heavy sections; 3 do not know and 15 did not reply. Three steel companies favor the specifications adopted by their association, which may be classed as low carbon. Since the inquiries for the congress of 1900 the wear of rails under the present service has convinced a number of railroad officials that harder rails were required to sustain the traffic.

The test of the comparative wear of high-carbon rails at the Grand Central Station, New York, of 100-pound section, with soft steel rails of like section, is decidedly in favor of the hard steel.

In 1895 the "inbound main" was laid with the high-carbon steel, and to date has carried over 250,000,000 tons of the present wheel-loads with a reduction of about one-sixteenth of an inch in height of the head of the rails. In 1900 some soft steel 100-pound rails were used and frogs made from them wear out in six to eight months, as compared to two and one-half to three years of the harder steel in the same location. Some of the soft steel

* The "Iron and Coal Trades Review," March 24, 1905. Abstract of a report presented to the International Railway Congress, May, 1905.

frogs were made from cold-rolled rails. Frogs made from the high-carbon rails have been in service at important points in the Grand Central yard from four to five years before renewal. The softer rails in the tracks, connecting the frogs and switches, show more rapid wear than those of harder steel. The loss in the height of the section is nearly twice as fast. The service tests show that the softer rails do not sustain the heavy wheel-loads of to-day as well as the harder high-carbon steel.

Tests of the unit fiber strains of the bending moments in the rails under moving trains show that in 80-pound rails, under present traffic, they are often 300,000 to 350,000 inch-pounds. If the elastic limits are not high, the unit fiber stress may exceed them and a set occur in the rail. With a stiffer 6-inch 100-pound section, with a unit fiber strain not greater than in the 80-pound, the bending moments might be increased to over 500,000 inch-pounds, under a wheel, without the metal taking a set. Unit fiber strains of 30,000 and even 40,000 pounds may occur daily in 80-pound rails under fast trains. These last for a small fraction of a second only, and are followed by a lighter stress of an opposite character.

As regards the use of nickel steel for rails, only four railways replied as having nickel steel rails in track. The accompanying table gives the chemical composition of the rails furnished by the Carnegie Steel Company to three of these roads, which were made by the open-hearth process and by the Bessemer process as indicated:

	Penn. Lines West. Open-hearth	Pennsylvania Bessemer	Pennsylvania Bessemer, 1903	N. Y. Central Bessemer, 1903
Nickel	3.52	3.22	3.50	3.40
Carbon	0.53	0.50	0.42–0.52	0.40
Silicon	0.05	0.13	—	0.11
Manganese	0.80	1.00	—	0.79
Phosphorus	0.14	0.09	—	0.09
Sulphur	0.02	0.03	—	0.04

The following is the record of the open-hearth rails laid on the Cleveland & Pittsburg division in comparison with carbon steel rails by the Bessemer process laid under the same conditions: Nickel steel rails laid in November, 1897, on .4 per cent grade. Bessemer rails laid in August, 1898, on .49 per cent grade. Both on 4° 42′ curves. Average speed of trains 44 miles an hour. Area of section worn off from surface of rail:

Bessemer, high rail .58 square inch, low rail .32 square inch; nickel, high rail .36 square inch, low rail .28 square inch.

The Bessemer nickel steel rails furnished to the Pennsylvania, which had an average composition as shown in the second column of the table, were of 100-pound section and were laid on the Horseshoe Curve during the winter of 1899–1900. The lowest nickel content in these rails was 2.83 and the highest 4.32 per cent; the lowest carbon was .419 and the highest .597 per cent. The wear of these rails was very satisfactory. In July, 1902, a report stated that since they were laid they had outworn two or three ordinary rails and were then only beginning to show signs of wear. Some of the rails were, however, too hard and some breakages had occurred. Subsequent orders for nickel steel rails for 5,000 tons of 100-pound section and several thousand tons of 85-pound section were furnished to the Pennsylvania by the Carnegie Steel Company and are now in service. These rails have a carbon content varying from .42 to .52 per cent with 3.5 per cent nickel. No reports have been received of the service of these rails.

There are several distinct forms of wear and deformation of the rails, which must be met by the physical and mechanical properties of the metal and section:

1. Surface wear of the heads, due to the rolling loads.

2. Surface wear of the heads, from adhesion of the engines to draw the trains.

3. Surface wear of the heads, due to the application of brakes to retard or stop the trains.

4. Surface wear of the heads, due to sanding the rails.

5. Oxidation of the surface of the rails.

6. Wear of the base of the rails on the cross-ties and under the spikes.

7. Wear and oxidation of the metal of the heads and bases of the rails at the fishing angles with the splice bars.

8. Wear and deformation of the metal of the facing ends of the rails at the joints.

9. Wear of the surface of the rail, due to gradients.

10. Wear and abrasion of the heads of the rails, due to curvature.

11. Wear and distortion of the surface of the rail-heads by hollow-wheel treads.

12. Large positive and negative bending moments and consequent unit fiber stresses to carry and distribute the wheel-loads, reversing with each passing wheel.

13. Large shearing stresses in the web of the rails connecting the positive and negative bending moments.

14. Thermal stresses due to changes of temperature, before the rail ends render in the splice bars.

15. Shearing stresses in the webs through the holes, due to the rails riding the bolts.

16. Excessive bending moments and shocks due to eccentric or flat wheels of the equipment.

17. Unexpected stresses in rails under service, from the difficulty of maintaining uniformly all parts in proper adjustment.

The progress in transportation in America, since replacing the limber by 60 to 70 per cent stiffer rail sections, is evident by the fast and heavy trains in regular service as the daily practice. Measurements of the " unit fiber strains " under moving locomotives, in the base of the same rail, and the determinations of the bending moments, show that without any other change the distribution of their total load may be modified by their construction of wheel base and wheel spacing, as shown by practice and " stremmatograph tests." They explain and confirm what has been the common belief of American theory and practice, since the inception of our railroads, — that the wheel base was the important factor in distributing the load to the rails, the cross-ties, ballast and foundation, — suitable designs reducing the total positive bending moments for the entire locomotive.

THE SURFACE FINISHING OF METALS *

REVIEW OF SCIENTIFIC METHODS OF STUDYING THE PHYSICAL STRUCTURE OF METALS BY AN EXAMINATION OF POLISHED SURFACES

By F. OSMOND and G. CARTAUD, Revue Générale des Sciences

DURING the past few years the study of the physical structure of metals used in engineering work has become very general. It is well understood that the methods of metallography should not be permitted to displace those of chemical analysis, while the records of the testing machine must always be employed by the conscientious engineer; but in many cases the microscopical examination of polished and etched surfaces will explain peculiarities of behavior, and reveal the consequences of manufacturing processes in a manner otherwise impossible.

Apart from the care which is necessary in the examination of the physical constitution of a metal under the microscope, an important element in the attainment of reliable results is found in the preparation of the surface of the material under consideration. For this reason the paper of MM. Osmond and Cartaud, in a recent number of the " Revue Générale des Sciences," is of especial value, especially as it includes the experience gained by the former engineer ot the Creusot Works, as well as that of an eminent French chemical engineer.

Leaving aside the details of etching and examining the metallic surfaces, the authors devote themselves especially to the preparation of the surfaces themselves, considering the methods of polishing or otherwise preparing the selected space for examination, and showing how this preparation may affect the results obtained.

Although the polishing of metals is one of the oldest of the arts it is one which has been almost entirely neglected in technical literature. Those investigators in the science of metallography who have made the most valuable contributions to our knowledge of the physical structure of metals have in nearly every instance been compelled to develop with their own labor the methods necessary to produce surfaces suitable for examination, while it

* " Engineering Magazine," May, 1905.

may be shown that when the surface is not properly prepared the conclusions drawn may be altogether misleading.

When the surface of a metal is reduced, either by a file or by such a medium as an emery paper, every tooth of the file and every grain of emery produces a scratch, the surface thus produced consisting of a mass of such scratches. Apart from the removal of the material effected by such means, the production of a scratch or similar break in the surface of a metal produces a very appreciable influence upon the material immediately surrounding, and as such methods form a portion of the operation of polishing preliminary to metallographical examination, these effects demand attention. Thus, when a depression is made in the surface of a metal by the point of a punch, or by a steel ball, as in the Brinell test for hardness, there will be produced what may be termed a series of undulatory waves in the mass of the material, and if the depression be produced far enough the deformation may develop lines of rupture within the material. In like manner the production of grooves or scratches by any tool, such as a file, will cause the development of internal stresses, so that the skin of the metal, as it may be termed, is in a different molecular condition from the interior of the mass. The extent of the effect of a scratch depends to a large extent upon the brittleness of the material. Thus the scratch of a diamond upon a piece of glass will affect the material so that it may be easily broken along the line of the break in the skin, while a scratch upon a material like gelatine or rubber may cause a more distinct break in the surface with a much shallower effect within the material. By examining scratched surfaces under the microscope the effect of the breaks in the surface upon the surrounding material may be studied, and the influence of the methods of preparing the surface is clearly visible.

The usual method of polishing a surface for metallographical examination includes the removal of a portion of the metal by some smoothing tool, such as a file, followed by a polishing by emery papers or cloth, of successive finenesses, the final specular polishing being effected by the use of some almost impalpable powder, such as rouge, tripoli, or as is now more generally employed, either alumina or chromic oxide, levigated according to the Schloesing process. By the use of such polishing materials a surface of a high degree of brilliancy may be obtained,

and this, after having been subjected to the corrosive action of some etching medium, can be studied under the microscope.

However complete the polishing may appear, the operation really differs in degree only from the earlier stages in the preparation of the surface. The gradual increase in the fineness of the abrading material acts simply to produce finer and finer scratches, until the visible marks have been replaced by invisible ones. It has been assumed that this operation removes the surface film, which, according to Beilby, differs in physical constitution from the metal beneath, and that a new strained surface film is not produced, but this does not necessarily follow. In many instances the highest and most brilliant polish acts simply as a mask to conceal the artificial skin from the eye, while the application of either chemical or mechanical revealers will demonstrate the fact that the altered surface layer is still there. These facts are clearly shown by reproductions of a number of microphotographs of etched surfaces, in which the action of etching solutions has brought out the lines and markings made by the operations of polishing the metal, and which to the untrained observer might give wholly erroneous ideas concerning the structure of the metal.

Another interesting method of revealing the existence of skin defects in a metal is the production of a new set of mechanical deformations. Thus, if deformation lines, sometimes called Lüders lines, such as are caused by punching or otherwise straining the material, be entirely polished out, so far as the eye can see, and the metal be subjected to a new method of deformation, such as pulling in a testing machine, the lines of the first deformation will re-appear upon the polished surface, showing that the molecular deformations had been masked only, and not removed. A similar action may be produced under the microscope, and a surface, apparently fully polished, will reveal surface lines if the skin be broken, as by the scratch of a diamond, if the specimen be subjected to pressure.

All these experiences go to show that the methods of preparation of a specimen for examination under the microscope act to create conditions of surface strain, amounting in some instances to an actual flow of the metal to an appreciable depth, and causing the polished surface to be very far from representing the true physical condition of the interior of the mass. It is

altogether possible to avoid these deceptive conditions, at least to such an extent as to reduce the surface film to such a slight depth as to permit it to be readily penetrated by the etching solution, and this means that the greatest care should be taken, not only in the final polishing, but in the preliminary reduction of the surface, and in all the details of preparation. The service which the science of metallography has rendered in extending our knowledge of the physical constitution of metals is very great, but it should always be remembered that it must be used with judgment and with such a degree of care and skill in all details as to permit the conclusions to be accepted with the same freedom from self-deception as exists in other methods of investigation.

THE USE OF DRY AIR IN BLAST FURNACES *

By A. POURCEL

Translated from the French for The Iron and Steel Magazine

IT seems likely, *a priori*, if not certain, as shown by Mr. Lodin in his note to the Académie des Sciences, that the fuel economy per ton of iron and the economy of motive force to be obtained, in Europe would not compensate the cost of erection and of maintenance of the apparatus required for drying the air. There are on the continent and even in France, some blast furnaces the fuel consumption of which is only 950 kilograms of coke per ton of iron with a burden containing only 33 to 34 per cent of iron against 63.50 per cent in the Isabella furnace, and with a fuel containing 15 per cent of ash and 5 per cent of water, while Mr. Gayley's coke contained only 11.50 per cent of ash. The amount of moisture was not given.

It appears quite certain that with a burden containing 43.50 per cent iron, these furnaces would reduce their coke consumption to 850 or even 820 kilograms. I refer here to the production of basic pig iron for the open-hearth furnace, containing less than 10 per cent of silicon, from 1.50 to 2 per cent manganese, from 0.05 to 0.06 per cent sulphur and 1.80 per cent phosphorus.

The blast of these furnaces, however, is heated to 700° C. instead of 375° or 400°. The cubic capacity per ton of iron in

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* "Revue de Métallurgie," January, 1905.

twenty-four hours varies between 2.5 and 3 cubic meters, while Mr. Gayley's furnace with a cubic capacity of 512 cubic meters produced 358 tons with ordinary blast and with dry air 447 tons. It will be remembered that Mr. Gayley has been the promoter of rapid driving. His paper on that subject read in New York in 1890 attracted much attention. The blast furnace which he then advocated (Edgar Thomson Works) was 27 meters high with a capacity of 550 cubic meters, while the coke consumption was from 775 to 840 kilograms per ton of iron, the furnace making 350 tons of acid Bessemer pig iron in twenty-four hours. The ore used contained 62 per cent of iron, the coke 10 per cent of ash, the blast temperature varied between 600° and 625° C., and 730 cubic meters of it was used per minute.

With rich and easily reduced ores, such as those of the Lake Superior, especially the soft hematite varieties, which are almost identical to the Bilbao ore now exhausted, fast driving is not objectionable — quite the contrary. Experience has shown, however, that such is not the case when using ore from Eastern France or Luxemburg. With these ores, and using furnaces with a capacity of 500 to 550 cubic meters, the production has seldom exceeded 150 tons of basic pig iron in twenty-four hours, and with a blast temperature exceeding 700° the pressure seldom reaches 40 cm.

The economy of motive force under these very different working conditions might be a negative one instead of approaching 136 horse-power which would result from Mr. Gayley's figures. At all events the saving of fuel obtained at the Isabella furnace may be explained in several ways. As stated by Mr. Le Chatelier the accuracy of Mr. Gayley's figures cannot be doubted and the scientific explanation he advances has a real value, but that explanation which rests upon the dissociation of the water vapor in the air seems also to be worthy of consideration.

Mr. Gayley did not attempt an increase of production from 358 to 447 tons before the furnace showed very uniform working as indicated by the regular descent of the charges, the absence of slips of partly reduced material, the decrease and regularity of the temperature of the waste gases, the variation between normal limits of the temperature of the blast when changing stoves, etc. This increased production was obtained with a smaller amount of

air, — 960 cubic meters instead of 1,130. The stoves were able to maintain the temperature of the air at 465° instead of 375° for the following reasons: (1) the weight of the air was decreased; (2) the air contained less moisture, and the calorific capacity of steam is more than twice that of the air; (3) the waste gases contained less moisture. The waste gases, although containing less CO (20 instead of 22.30 per cent), contained less moisture and had a higher calorific power.

The heat generated at the tuyères must have been greatly increased to make it possible for the same amount of coke to stand the increase of burden indicated by Mr. Gayley without any material change in the nature of the pig iron produced, except a *necessary* decrease of manganese. This is due, as conclusively shown by Le Chatelier, to the desulphurizing of the metal resulting from a decrease of moisture, which permits a decrease of the basic character of the slag, making it more fusible and decreasing its calorific capacity (400 rather than 500 calories) but for the same reason diminishing the quantity of manganese absorbed by the metal. This, however, is not a serious objection in the case of basic pig iron for the open-hearth furnace, the chief characteristics of which should be a small amount of silicon and of sulphur. In Eastern France, Luxemburg and Germany such pig iron is designated by the mark "M.O.," which signifies without manganese.

It seems evident, without further insistence, that this set of conditions must result in a notable increase in the quantity of calories available in the crucible of the furnace. Finally, with dry air, the loss of heat at the level of the tuyères, which results from the dissociation of water, is suppressed as well as the increase of temperature resulting from its re-formation ($CO_2 + H_2 = H_2O + C$) in the bosh, where it causes a viscosity of the mass, increasing its tendency to stick to the furnace walls. The fall of these agglomerations of partly reduced material, which takes place periodically, when they have reached a certain size, causes a cooling of the furnace and, therefore, a deterioration, more or less marked, of the iron.

To sum up, the temperature is lowered in the furnace region where its increase is hurtful in producing this stickiness of the mass, while there is an increase of the zone where the carbonic oxide is susceptible of decomposition ($2\ CO = C + CO_2$), thereby

carburizing the ore. This carbon impregnation due to the decomposition of CO begins at 200° C., reaches its maximum at 450° and ends at 800°. It is especially this carburizing action which is an important factor in the saving of fuel in the reduction of the ore. The longer its duration (through an extension of the zone where it takes place) the smaller the proportion of CO in the escaping gases, and, therefore, the smaller the coke consumption per ton of iron.

It is not without reason, therefore, that the effect of the dissociations of the water may be offered as one of the causes explaining the economy observed at the Isabella furnace, following the drying of the air.

Mr. Gayley observed also, as a result of drying the air, a decrease in the phosphorus content of the iron, and a decrease amounting to 5 or 10 per cent in the loss of ore carried away by the gases. The first result can only be explained by the smaller amount of coke used if it contains much phosphorus, which is not stated. The second result may be explained by the decreased pressure of the escaping gases resulting from their lower temperature (191° C. instead of 281° C.). It is always dangerous to prophesy and in the present case it would be running the risk of being a bad prophet in predicting that the large producers of pig iron of the continent of Europe will never find an immediate profit in adopting Mr. Gayley's conceptions. This conception in itself is logical: the drying of the air blown into a blast furnace may result in a more regular working and in a more or less appreciable economy of fuel; it only remains to discover a means of effecting this, less complex and therefore less costly than the one patented by Mr. Gayley.

THE USE OF DRY AIR IN THE PRODUCTION OF CAST IRON *

By O. BOUDOUARD

Translated from the French for The Iron and Steel Magazine

SINCE the publication of Mr. Gayley's paper, French metallurgical engineers have remained skeptical regarding the given results. The rational explanation of the fuel economy resulting from the use of dry air has already been discussed in several

* "Revue de Métallurgie," February, 1905.

papers, in which, unfortunately, it has only been possible to discuss hypotheses. Mr. Le Chatelier, in a recent article, while stating that it would be very costly to conduct experiments under the conditions described by Mr. Gayley, expressed his belief that laboratory experiments could readily be conducted with a view of studying the equilibrium conditions of carbon monoxide with carbon and iron ore or of water vapor with calcium sulphide, and that such experiments might throw additional light upon the question. Guided by these suggestions, I endeavored to ascertain the influence of moisture upon the reduction of iron oxides.

The work of Lowthian Bell, Grüner, Deville, Debray, Tissandier and Moissan is well known, but these scientists used only dry gas. Mr. Moissan states that for the reduction of iron oxide at the temperature corresponding to the softening of glass, it is necessary to employ perfectly dry gas, because of the secondary actions.

In a first series of experiments a mixture of equal volumes of carbon monoxide and dioxide, such as results from the decomposition of oxalic acid by sulphuric acid, was passed over some sesquioxide of iron. The gases were either dried by passing them through sulphuric acid or else they were saturated with moisture by passing them through water. The ferric oxide placed in a small porcelain boat was weighed before and after the experiment, and from the loss of weight the amount of reduction was calculated. The boat was heated by means of an electrical furnace the temperature of which was ascertained by a thermo-electrical couple. Each experiment lasted one hour and the gas was passed at the rate of six liters per hour. The boat was allowed to cool in a reducing atmosphere.

The results obtained are tabulated below, the figures indicating the loss of weight in percentage:

Temperature Deg. Cent.	Loss in per cent of the weight of Fe_2O_3 $CO+CO_2$ Dry	$CO+CO_2$ Moist
550	4.3	3.8
800	4.0	2.65
925	5.6	4.4
1,050	6.5	6.9

The theoretical loss of oxygen for the reduction of Fe_2O_3 to Fe_3O_4 is 3.33 per cent, that for the reduction to FeO is 10

per cent and for the reduction to Fe, 30 per cent. The product obtained is therefore a mixture of the two oxides, Fe_3O_4 and FeO. It can be attracted by a magnet.

In the second series of experiments, I studied the reducing action of pure carbon monoxide obtained through the decomposition of formate of sodium upon ferric oxide resulting from the calcination of ferrous oxalate. The experiments were conducted in a similar way with the exception that the velocity of the gas was reduced to about 4½ liters per hour. The following results were obtained:

Temperature Deg. Cent.	Loss in per cent of the weight of FeO CO Dry	CO Moist
850	15.3	11.0
1,050	21.5	21.5

The theoretical loss of oxygen in reducing FeO to Fe is 22.22 per cent at 1050°, the reduction was therefore practically complete. The product was very magnetic. From these experiments it clearly follows that reducing gases have a more energetic action when dry than when moist; the difference, which is marked at low temperatures, disappears at about 1000°, and this is true both in the reduction of Fe_2O_3 by equal volumes of CO and CO_2, and in the reduction of FeO by CO. In the cooler region of a blast furnace, with dry gases there will be, therefore, a more complete reduction of the iron oxide by carbon monoxide, and as it is known that the reaction of the carbon dioxide thus formed upon the carbon is the less pronounced the lower the temperature, it must result in an economy of fuel. It must be remembered, however, that in blast furnaces, at the level of the tuyères, the moisture is decomposed into hydrogen and oxygen, and that we have no accurate knowledge regarding the subsequent action of hydrogen, which, in presence of carbon dioxide, may regenerate water vapor and carbon monoxide.

METALLOGRAPHY APPLIED TO FOUNDRY WORK *

By ALBERT SAUVEUR

IN this series of short articles, I propose to present as concisely and simply as possible the elements of metallography with special reference to the application of this testing method to foundry work. I shall avoid dealing with hypotheses or with theories, which are still to a great extent of a speculative character, as well as with scientific considerations of no immediate practical application. In short it will be my aim to convey such a knowledge of metallography as will be of value to those engaged in the production of castings.

The Fracture of Cast Iron vs. its Micro-Structure. — As is well known, foundrymen from time immemorial have been in the habit of judging of the grade of pig iron by the appearance of its fracture. In recent years moderately successful efforts have been made to replace this relatively rough and uncertain test by the more accurate and scientific method of chemical analysis. Many foundrymen, however, are still guided by the appearance of the fracture in selecting pig iron for their mixture. With all its shortcomings and limitations, the fracture test undoubtedly furnishes to the trained eye much reliable information regarding the chemical composition of the iron. The reason for this is to be found in the close relation which exists between the aspect of the fracture of a metal and its physical and chemical characteristics. Indeed, it may be confidently asserted that any treatment which affects the chemical or physical properties of a metal will also affect the appearance of its fracture. If this be so, it only remains for us to learn how to read and interpret these changes in the aspect of the fracture in order to obtain the needed information regarding the properties of the metal. As might well be expected this will demand considerable experience on the part of the observer. The fracture of a metal is not an open book in which any one may read. A long preliminary schooling is generally required, and even to the proficient student the book yields, undoubtedly, but a very small part of the secrets which it encloses. The little which it does yield, however, is generally of sufficient value to warrant the effort of acquiring

* The "Foundry," May, 1905.

the necessary training. Many instances of notable proficiency in fracture reading are on record; such, for instance, as the remarkable accuracy with which skillful and experienced smiths are able to determine the refining heat (recalescence point) of steel by the appearance of the fracture, and the close estimate made by crucible steel makers of the carbon content of their steel based solely upon fracture inspection. If it be considered that in this study of fracture reading we have hardly passed the spelling stage, we may confidently expect fruitful returns as a reward for further endeavor.

Seeing the closeness of the writing and the jealous care with which the metal seeks to hide its secrets, it was quite natural that metallurgists should have called to their assistance those instruments of modern research which in other fields had been used with such wonderful results, namely the magnifying glass and the compound microscope. In examining the fracture of metals by means of a magnifying glass we are occasionally able to obtain information which the naked eye could not secure, but it is, on the whole, of but slight assistance. The examination of the structure of metals, on the contrary, by means of a compound microscope, opens up almost unlimited possibilities. A wonderful light is thrown on the page which we were reading so laboriously; new words, new sentences, appear, and we have taken a step forward in our knowledge of metals which mark an epoch in their study.

The compound microscope, however, cannot be applied to the examination of fractures, the magnification which it yields being so great that only perfectly plane surfaces can be observed. The inequalities of a fracture when so highly magnified become as many mountains and valleys; if we focus our eye upon the summit of a mountain the valley will be so far away as to be but dimly visible, while if we bring the valley within visible distance, the mountain tops lie so near our eye as to be quite undistinguishable.

In order to apply the microscope to the study of metals, it is, therefore, necessary to use polished sections, suitably prepared. The micro-structure of the metal is in this way revealed. That a close relation must exist between the fracture and the micro-structure seems likely, if not certain, but the fracture is like a page roughly written with a blunt pen which can be read

only imperfectly and with much labor, while the micro-structure may be compared to a beautiful page of calligraphy in which every letter is perfectly formed.

It will be seen that the microscopical examination of metals may be regarded as an extension of fracture study. It is still an inquiry into the properties of metals by an ocular examination of its structural components, but it is an infinitely more searching and effective method than mere fracture study with the naked eye.

The superiority, in some respects, of the microscopical examination over chemical analysis may be shown by the following considerations: The properties of a metal do not depend so much upon its ultimate composition as upon its proximate composition. Some substances may have exactly the same ultimate composition and still have widely different properties because they differ in proximate composition. The chemical analysis of metals as conducted at the present day furnishes us only with the ultimate composition, that is with the percentage of the *elements* the metal contains; it yields no information with regard to the way these elements combined with each other to form the metal; in other words, it fails to suggest its proximate analysis. The microscopical examination of a metal, on the contrary, is a step, and a most important one, towards this proximate analysis. It reveals the constituents of the metal such as they exist. It does not tell us that the iron contains so much carbon but so much carbide of iron (Fe_3C), and it shows the way in which this carbide of iron is associated with the balance of the iron; it does not merely give the amount of iron present but the number of grains of iron, with their size, shape and distribution.

Again, it is well known that slight changes of heat treatment may greatly affect the properties of a metal, while it generally leaves its ultimate chemical composition unaltered. In this connection chemical analysis utterly fails to assist us in detecting and interpreting these changes. The micro-structure of the metal on the contrary is closely related to any change of properties, and the effect of heat treatment may always be detected in the structure.

The Technology of Metallography

Polishing. — As already mentioned, in order to examine the structure of cast iron under the microscope it is necessary to

prepare a polished section of the metal. As it is, of course, desirable to shorten as much as possible this operation, it is recommended that sections be prepared not exceeding one-half inch square or one-quarter inch in square area. After a little practice and with the assistance of a suitable polishing outfit, the time required to prepare a sample of this dimension should not exceed ten minutes. Larger samples will demand considerably more time.

Samples of cast iron suitable for microscopical examination may readily be cut from test pieces or other castings by means of a hand hack saw, or better still by means of a power hack saw. Samples of white cast iron must, of course, be broken or cut with a thin emery disk.

The polishing should be conducted with care, and a surface produced quite, if not altogether, free from even the minutest scratches, because such markings when highly magnified might seriously interfere with the resolution of the structure.

If the sample has a very rough surface some time may be saved by filing it with a smooth file. It is then ready for the polishing operation.

To remove the file or saw marks and obtain a surface free from scratches the sample must now be rubbed successively over several abrasive substances of increasing fineness, for it is not possible to obtain such a specular surface in one operation; the transformation must be gradual.

In the following pages it will not be attempted to review the various methods which have been advocated by different workers, but merely to describe briefly those methods which I have found to yield the most satisfactory results.

Hand Polishing. — Roughly speaking, the polishing of samples of metals for microscopical examination consists in three treatments: (1) two or more polishings with emery (or carborundum) of increasing fineness, (2) polishing with an intermediate powder such as tripoli, crocus, diamondine, etc., and (3) polishing with jeweler's rouge. Some writers recommend the preparation by each worker of his own powders, but I find no difficulty in obtaining very good surfaces with the best grades of the powders of commerce.

While much time is to be saved by the use of some simple polishing machine, the operation may be conducted entirely by

hand, in which case the following procedure is recommended. Four very smooth and perfectly level blocks of wood should be obtained, measuring, say, 6 by 12 inches and 1 or $1\frac{1}{2}$ inch thick. Upon two of these blocks a piece of cotton cloth should be tightly stretched and fastened by tacks to the four sides, while upon the

Grinder for Preparing Specimens

other two blocks, pieces of fine broadcloth should be similarly stretched and fastened.

A small amount of emery powder No. 80 should now be poured on one of the polishing blocks covered with cotton cloth, and mixed with sufficient water to form a thick paste. This paste should be spread over the block, conveniently by means of a spatula, and with the addition of a little more water, if necessary.

The sample of metal, which should have been previously carefully filed with a smooth file, should now be rubbed back and forth over this block at right angles with the file marks, without changing its position until the latter have been removed and replaced by finer markings due to the action of the emery powder. The sample should be carefully washed — preferably in running water — as well as the fingers of the operator, and then rubbed over the second polishing block, covered with cotton cloth and some flour emery of the best quality, precisely as before. The specimen should be held in such a way that the new marks cross the old ones at right angles, because the complete disappearance of the latter can then be more readily detected. The sample, after being carefully washed, is ready for the next treatment. Some of the tripoli powder should be spread, with the addition of water, over one of the blocks covered with broadcloth, and the specimen rubbed over this block until all the markings left by the fine emery are replaced by finer ones running at right angles. After careful washing the sample should now be rubbed over the last polishing block, covered with fine jeweler's rouge and water, until all the scratches have been removed. In the case of gray cast iron many small irregular cavities can be detected by the naked eye, but these mark the location of the graphitic carbon, and will be readily distinguished from scratches. A magnifying glass is very useful in inspecting polished specimens.

The polished sample should now be carefully washed and dried with a soft cloth — preferably an old piece of linen. Where an air blast is at hand, as is generally the case in chemical laboratories, it is advised to dry the specimen by means of this blast instead of drying it with a cloth, because by so doing we diminish the danger of scratching it. Even after drying by the air blast, however, the sample will generally have to be gently wiped with a cloth.

In conducting the polishing operation, the student is advised to press the specimen lightly over the polishing block, especially when using the fine powders. Great care should be taken not to carry any coarse powder over a polishing block upon which a finer powder is used, as the presence of but a few particles of coarser powder will greatly lengthen the operation. It is, therefore, of much importance to keep all the blocks carefully

covered when not in use, as well as the bottles containing the powders. Cardboard covers will readily be procured to cover the polishing blocks.

Polishing Machine

The use of some simple power-driven polishing machine naturally suggests itself to hasten the polishing operation. In Fig. 1 is shown a device which has given excellent results and which is widely used. It consists of a grinding machine of the usual style, carrying four disks revolving in a vertical plane: the first disk is an emery wheel of suitable grade, the second a cast-iron disk covered with canvas, and the next two, wooden or cast-iron disks covered with broadcloth. A simple arrangement permits the quick removal of torn cloths whenever necessary. Flour emery, tripoli powder and rouge are respectively applied at the center of the three last disks in the shape of a thick paste, conveniently by means of a brush while the machine is running. Water may be added from time to time as needed in a similar manner. Shields are provided for catching the water thrown off the disks. The sample is pressed in succession over these four surfaces, observing the precautions outlined for hand polishing.

With such an outfit it should not require over ten minutes to polish a sample of cast iron measuring one-half inch square, and frequently a much shorter time will suffice.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

A NEW **Process for Refining Pig Iron.** J. B. Nau. "The Iron Age," March 23 and April 6, 1905. 8,000 w., illustrated. — This paper treats of the operation of refining pig iron by means of iron ores. The method has been devised with the special aim of applying it to the preliminary and partial refining of pig iron too high in silicon as well as phosphorus to be treated economically in the open-hearth furnace. It is especially in our Southern districts that pig irons high in silicon, phosphorus and sulphur are a common occurrence. They contain too much phosphorus for acid open-hearth practice, too little of it for basic-Bessemer, and their high and irregular silicon contents make them a very undesirable raw material for treatment in the basic open hearth.

From the results obtained in England by Sir Lowthian Bell, and from those obtained on a large, practical scale in the Krupp process, still working in this country, and from Mr. Uehling's tests, it is apparent that the refining of pig iron by iron ore should be performed in a short time and at as low a temperature as will be consistent with an easy and complete success. The rapidity of the operation depends on the intimate contact between the liquid metal and the purifying ore.

All these conditions can be realized in practice in an apparatus of the kind shown in the accompanying engraving. The vessel, in the form of a cupola, may be erected in the immediate

* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

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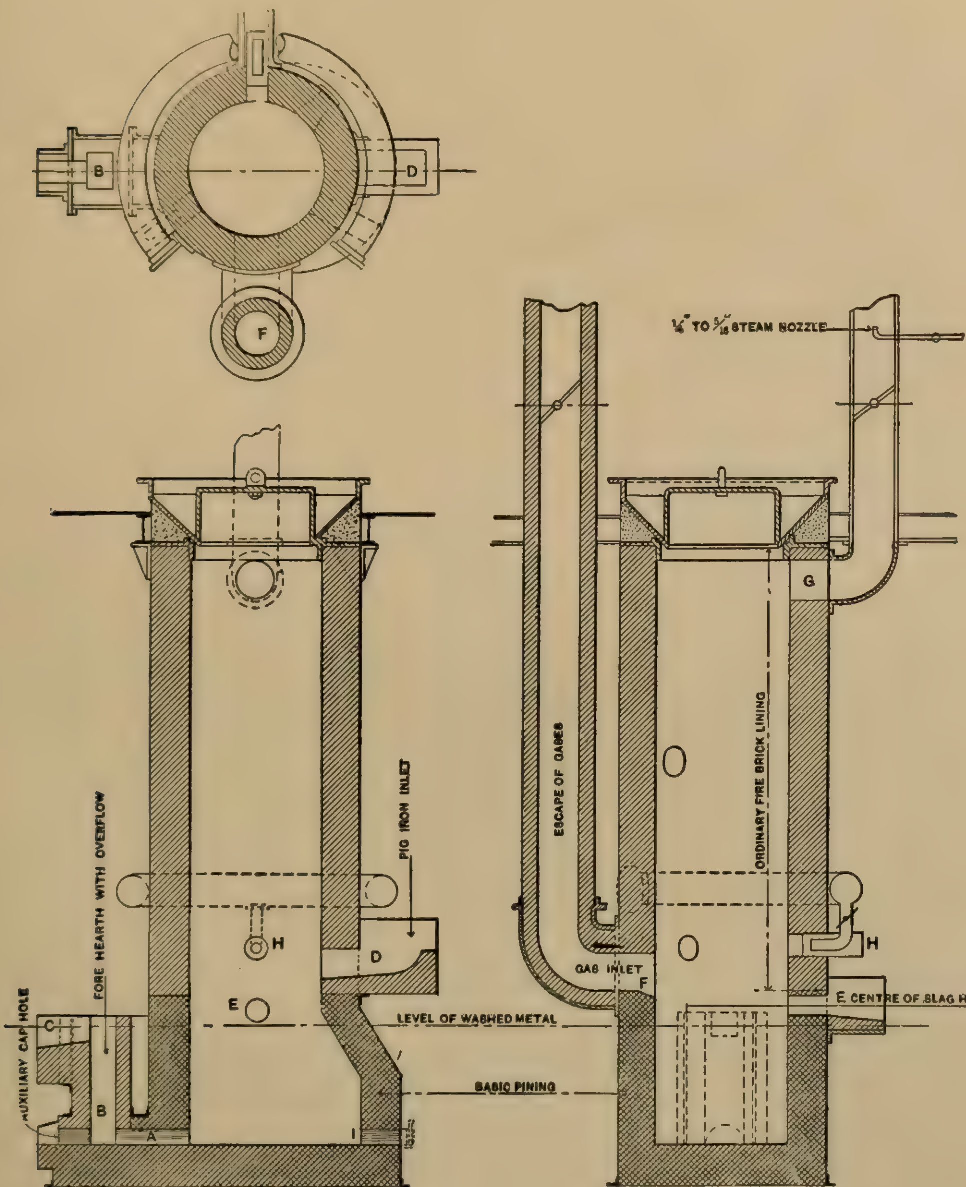
neighborhood of the blast furnace. It is provided with a basic, or neutral, lining on the bottom and over the whole height of the purifying zone and with ordinary fire-brick lining in the upper region. An inlet for liquid pig iron is shown in D; an outflow,



A, near the bottom connects the cupola with a fore hearth, or riser, B, provided near the top with an overflow, C. A little higher up is located a slag hole, E. A circular bustle pipe above the inlet D supplies hot blast or air or heating gas through

tuyères, H. Near the bottom of the riser is an auxiliary tap hole, to empty the vessel toward the end of the operation. In F, a little above the purifying zone, the gases generated during the operation have a free outlet without passing through the ore in the upper part of the cupola. These gases, naturally of a reducing nature, are thereby effectively prevented from occasioning a possible premature reduction of the ores in the upper part of the cupola before they reach the refining zone. If necessary, provision may be made to admit air to the region above the reducing zone for the purpose of burning the gases produced in the refining zone and letting the products of combustion rise through the ore body, thereby heating this latter very economically. The outlet F remains and acts as a safety opening in case of a sudden development of a large volume of gas. At G, just below the hopper, is a smokestack.

The operation is as follows: The cupola when empty is heated by means of blast furnace or other gases or hot blast, introduced through the riser B and the tuyère H. Draft is obtained through the suction created by the steam from the nozzle in the smokestack or by means of an exhaust fan. After the cupola has been sufficiently heated it is filled to the top with pieces of rich ore of the size of a fist and larger, which are then heated by the same means to the desired temperature.

Liquid pig iron may now be run directly from the blast furnace through D. The iron striking the ore and percolating through it is partly refined while falling to the bottom of the cupola. Here its level is allowed to rise through the ore until, after sufficient purification, it reaches the height of the outflow C, when it flows off. The slag formed during the operation rises on top of the metal and flows off through E. The ore is kept immersed in the bath by means of the pressure of the ore higher up, and as fast as it is consumed in the operation and is slagged off it is replaced by the ore immediately above, which is continuously pushed down under the weight of the fresh supplies charged through the hopper. The immersion of the ore in the bath is also very materially helped by the weight of the liquid pig entering the purifying apparatus and falling on the pieces of ore below, which has naturally a tendency to carry them down.

Since it is possible to heat to a temperature most favorable to the rapid refining it is presumed that sufficient purification

can be obtained after five to eight minutes of contact. At any rate the length of this contact may easily be regulated by the change of the relative levels of the different openings so as to suit existing conditions in regard to the chemical composition of the iron and the ore. A little testing will easily establish the right conditions.

The presence of the riser affords the advantage that no piece of ore will interfere with the free outflow of the purified iron, because the ore, being much lighter than iron, will always have a tendency to rise in the bath and keep above the outlet A. At the same time the most refined metal, being the heaviest, will always be found near the bottom.

Since the apparatus makes it possible to keep the level of the ore always at the same height, the amount of immersion and contact will remain the same throughout the operation, which naturally will induce uniform refining and this whether a large or a small quantity of iron be purified in one operation. This is important since it permits adapting the method equally well to a small or a large blast furnace. At the end of the operation the vessel is emptied through the auxiliary tap hole near the bottom of the riser.

Throughout the height of the shaft convenient openings should be provided, closed with easily opened doors, to help the descent of the ore should this be found necessary. Large cleaning doors should also be located near the bottom, kept tight during the operation but allowing of easy cleaning.

The heating of the cupola may be done either by means of blast-furnace gas or hot blast or hot air. **No. 362. B.**

De l'Utilisation des Gaz de Haut Fourneau (Utilization of Blast-Furnace Gases). Ch. de Mocomble. "Revue de Métallurgie," January, 1905. 40,000 w. — This is the most exhaustive and probably the most authoritative treatise yet written dealing with this important and timely question. The author divides his subject into four chapters. In the first chapter he studies the blast furnace, Grüner's experiments, and the high English and American stacks. In the second chapter the actual utilization of blast furnace gases for heating the stoves is carefully considered. In the third chapter the author studies the use of waste gases for raising steam and in the fourth chapter the

utilization of those gases in internal combustion engines. He concludes as follows:

"Bearing in mind the figures given in our introduction, it will be readily seen that the utilization of the waste gases of blast furnaces constitute an immense progress, and that the metallurgical industry will derive great benefits from the substitution for steam engines of internal combustion engines.

"The day is still far away when all the gas produced will be utilized, but it will be admitted, if we consider the remarkable development of this new application, that no metallurgical plant can afford to ignore it if it is not to be distanced by its competitors. The available energy cannot always be immediately utilized, but new industries are created where they can be readily developed, Switzerland, the Niagara, and, nearer us, the Dauphiné, afford as many striking instances of this.

"The first gas-blowing engine was tried ten years ago, and four years ago the new 600 horse-power Cockerill cylinder was received with surprise and skepticism. To-day 1,500 horse-power cylinders are constructed, giving engines of 3,000 and even 6,000 horse-power. Notwithstanding such brilliant results it might be recalled that in 1895, when Mr. Thwaite suggested his method for the utilization of blast-furnace gas, he met with absolute incredulity. The ironmasters to whom he appealed ridiculed the idea, saying that it was absurd to expect that a gas so poor that it is sometimes impossible to keep it burning under the boilers, would ignite regularly under the conditions which must be met for the working of internal combustion engines. Mr. Riley, the manager of the Glasgow Iron Company, alone understood that this was not an Utopia, and with an initiative which could not be too highly commended, he replaced the steam engine of his electrical power station by the first gas engine working with blast-furnace gas. This installation, although it only includes a small motor, is nevertheless very interesting, as it gave excellent results and justifies the inventor's statement that 'the moment the fly wheel of this gas engine made its first revolution marked an important date in the history of the metallurgy of iron.' Since then, how much has been accomplished! But it must be remembered that if the construction of these blast-furnace gas engines has in a few years so markedly progressed, it is due to the cleansing of the

gases. The only stationary period recorded at the beginning was due to an incomplete cleaning of the gases, it having been deemed useless to attempt a more thorough cleaning. This cleaning may be considered as the vital question of the gas motors." **No. 363. E.**

Gas Blowing Engines. Tom Westgarth. "Iron Age," April 13, 1905. 2,300 w., illustrated. — Abstract of a paper presented before the West of Scotland Iron and Steel Institute, February, 1905. **No. 364. B.**

Fabrication de l'Acier dans les Usines de la Société Electro-Métallurgique Française a La Praz (Savoie). (Manufacture of Steel at the Works of the Société Electro-Métallurgique Française, at La Praz.) Charles Combes. "Revue de Métallurgie," January, 1905. 12,500 w., illustrated. — A paper presented to the Société d'Encouragement, December 9, 1904. The author describes at length the manufacture of steel by the Héroult process as conducted at La Praz by the Société Electro-Métallurgique Française, better known under the name of Société de Froges. For the last two years the society has placed on the market high-grade tool steel comparable to the best crucible steel. A gold medal has been awarded this company, for its exhibit at St. Louis. In 1887 Héroult obtained a patent for his first model of electrical furnace which was soon widely used for the reduction of refractory oxides. In 1899 this furnace was employed at Froges for the production first of ferro-chrome and later of ferro-silicon and ferro-tungsten. The manufacture of ferro-chrome proved so successful that it was promptly adopted by others and it may be said that the production of that alloy in the blast furnace has now been abandoned. Ferro-chrome which before the use of the Héroult furnace was worth 1,800 francs per ton can now be obtained for 700 or 800 francs per ton. In his early furnace, Héroult used a carbon lining, but this was later replaced by other refractory materials such as chromite, and it became possible to obtain ferro-chrome containing much less carbon, which is a desideratum. The possibility of producing slightly carburized metal in the electric furnace led Héroult to apply it to the manufacture of steel, and this method is well known to our readers. **No. 365. E.**

Recent Developments in Electric Smelting in Connection with Iron and Steel. F. W. Harbord. Paper read before the Faraday Society, March 6, 1905. 12,000 w., illustrated. — The author reviews the various methods which are being used for the electric melting of iron ore and the refining of pig iron and discusses their relative merits. The substance of the paper will be found embodied in the Canadian Report from which also many of the illustrations are reproduced. **No. 366.**

The Present Status of Electric Furnace Working. Charles F. Burgess. "Journal of the Western Society of Engineers," April, 1905. 9,000 w., illustrated. — This paper is a very able and instructive review of the electric furnace and its possibilities. **No. 367. C.**

Sur l'Évolution de la Structure dans les Métaux. (Evolution of the Structure of Metals.) G. Cartaud. "Comptes Rendus." 1,500 w. — The most fusible metals (lead, tin, zinc, etc.), which are also the softest, had until now escaped the usual metallographical technology, which consists, as is well known, in polishing and etching some sections of the metal cut from ingots. Following Ewing and Rosenhaim these soft metals were cast upon a highly polished surface. Our methods make it possible to treat these metals like the others and to polish in a satisfactory manner a section of zinc, tin or lead.

Lead, which is the metal most difficult to polish, is also the metal which has yielded the best results. A treatment with a solution of picric acid in acetone reveals the presence of a microscopical network completely closed. By a succession of treatments with picric acid alternating with polishing upon a cloth covered with chromic acid moistened with ammonia, the superficial layer of cold worked metal may be eliminated. A network is still revealed, but the meshes are infinitely greater. They are formed by the junction lines between the crystals of first consolidation, those which are to be found in a metal which has not been distorted after its solidification. "Revue de Métallurgie," February, 1905. **No. 368.**

Micro-Structure of Annealed Steel. W. Kurbatoff. "Jurn. Russk. Fisik. Chimicesk. Obscestva." — This paper is given up

to investigating the various etching substances which might be used for ascertaining the different structural constituents of steel, it being shown that the rate of etching is about proportional to the degree of electrical dissociation. Solutions in water give rather unsatisfactory results, while solutions in a non-dissociated liquid do not lead to any coloring effect. If there be added to the active caustic liquid some $C_6H_4(NO_2)(OH)$, or a similar substance, the effect of the caustic is altered so as to warrant the conclusion that the colored fracture has a complicated composition. The results of the investigation can be summarized as follows: (1) A 5 per cent solution of nitric acid in isoamylic alcohol was tested and found to be the most sensitive of all those experimented on, allowing the structure of soft steel, brittle and not brittle, to be distinguished from the lamellar structure of nickel steel. (2) A mixture of 1 part of a 4 per cent solution of the same nitric acid in acetic anhydride and one part of methyl, ethyl and amyl alcohols was found, after acting for seven to ten minutes, to color only troostite and sorbite, leaving the remaining constituents unaltered. The problem as to a possible difference in hardness between austenite and martensite was next investigated, it being shown that the hardness of the crystals regarded as austenite is different, not only in different specimens, but even in the same specimen. The structure of steel containing high percentages of carbon (1.9 per cent C.) was next studied in connection with tempering, the following being recognized: (1) On being tempered at different instants of the transition period ($A_{r\,1,\,2,\,3}$), this steel consists of sorbite and cementite. (2) With high temperatures dark crystals on a bright background and troostite, and with still higher ones, bright crystals on a dark background are obtained. (3) During annealing, martensite is separated into plates of cementite, troostite being converted into cementite. Austenite is converted into troostite. (4) On raising the annealing temperature, the following reaction is found to take place: troostite + cementite is converted into ferrite + cementite, while the percentage of cementite is increased. The author is inclined to think that all the constituents of steel, being solid solutions of carbides and carbon in iron, may crystallize in large crystallic aggregates of the same system. "Science Abstracts," March 25, 1905. **No. 369. C.**

Increase of Volume of a Liquid Casting, Saturated with Carbon in the Electric Furnace, at the Moment of Solidification. H. Moissan. "Comptes Rendus," January 23, 1905. — An iron casting made in a conical mold, like water frozen in a similar vessel, exhibits a central hollow, which suggests a contraction during solidification. That an expansion actually occurs was first shown in 1726 by Réaumur. Wrightson ("Iron and Steel Inst. Journ.," 1880) noted an expansion from 15.28 inches to 15.36 inches during the solidification of a sphere, and found that the density at the center when cold was 6.95, but at the circumference 7.13 — a result that was attributed to the internal pressure produced by expansion. This result was confirmed by the statement of Bell, that the solid always floats on the surface of the liquid. In a recent series of experiments the author found that Swedish iron melted by an electric current in a crucible of magnesia, and containing less than 1 per cent of carbon, solidifies quietly without giving any indications of expansion. But when the iron is saturated with sugar charcoal, melted in a graphite crucible, and allowed to cool quietly in the air, the solidification of the surface is usually followed by an eruption of the liquid interior, which solidifies at once when the pressure is released. Occasionally no such eruption occurs, but the surface of the ingot is then rough and swollen, and a part of the carbon is in the form of diamond, testifying to the pressure existing in the interior. The instantaneous solidification of the released metal sometimes causes it to take a form strikingly similar to the lava plug of Mont Pélée. The carbon content of the specimens examined varied from 7.65 to 8.17 per cent. Incidentally it was noticed that the molten iron does not moisten the surface of the magnesia crucible, but in the graphite crucible the metal wets the crucible, and is drawn up the sides by capillary attraction. "Science Abstracts," March 25, 1905. **No. 370. C.**

Some Conditions Governing the Production of Iron and Steel Castings. Percy Longmuir. "The Engineering Review," March and April, 1905. 7,000 w., illustrated. — The author describes the influence of composition and treatment both upon the structure and the properties of iron and steel castings. **No. 371. B.**

The Hughes Annealing Furnace. "Iron Age," April 20, 1905. 1,100 w., illustrated. — An illustrated description of a furnace for annealing steel castings, nickel steel plates, eye bars, etc., invented by Johnson Hughes. **No. 372. B.**

The Design and Operation of the Suction Gas Producer. Rodolphe Mathot. "The Engineering Magazine," May, 1905. 4,000 w., illustrated. **No. 373. B.**

Gas Producers in Iron Works. Otto Wolff. "The Iron and Coal Trades Review," April 14, 1905. 3,500 w., illustrated. — A paper read before the Association of Ironmasters in Southwest Germany, at Saarbrucken, January, 1905. **No. 374. B.**

Windtrocknung und Turbogebläse. (Dry Blast and Turbo-Blowers.) W. Mathesius. "Stahl und Eisen," March, 1905. 1,800 w. — The author describes the removal of moisture from the air by the use of some chemicals. **No. 375. D.**

Gayley's Dry Air Blast. F. A. Wilcox. "The Iron and Coal Trades Review," March 31, 1905. 2,200 w. **No. 376. B.**

The Relation of Theory to Practice in Steel Metallurgy. J. O. Arnold. "Journal, West of Scotland Iron and Steel Institute," January, 1905. 6,000 w. — Abstract of a lecture. **No. 377.**

Notes on the Evolution of Blast-Furnace Recovery Plant. J. Gillespie. "Journal, West of Scotland Iron and Steel Institute," January, 1905. 6,000 w., illustrated. **No. 378.**

Verwendung von Kalt Erblasenen Roheisen zur Flusseisendarstellung. (The Use of Cold-Blast Iron for the Manufacture of Low-Carbon Steel.) Dr. Geilenkirchen. "Stahl und Eisen," March 15, 1905. 4,500 w. — The author discusses the relative value of hot- and cold-blast iron for the production of steel by the open-hearth process. **No. 379. D.**

METALLURGICAL NOTES AND COMMENTS

E. H. Saniter E. H. Saniter, a recent photograph of whom we reproduce as a frontispiece to this issue, was born at Middlesbrough, England, in 1863, and received his early education at Sir William Turner's grammar school, Coatham Redcor. For three years he studied chemistry in the metallurgical laboratory of J. E. Stead, and from 1883 to 1890 was assistant chemist at the North Eastern Steel Works, Middlesbrough. From 1890 to 1897, Mr. Saniter held the position of head chemist at the Wigan Coal and Iron Company, Wigan. During 1891 and 1892 he invented and brought to a successful issue his well-known Saniter Process for Desulphurizing Iron and Steel. This process he described in several papers presented to the Iron and Steel Institute (September, 1892, and May, 1893), to the Cleveland Engineers Society, to the Staffordshire Society of Iron and Steel Works Managers and to the West of Scotland Iron and Steel Institute. Among Mr. Saniter's other technical writings the following papers may be mentioned: "Carbon and Iron" and "Allotropic Iron and Carbon," presented to the Iron and Steel Institute; "A Review of the Methods for Estimating Manganese in Minerals and Metals" and "A New Method of Estimating Chromium in Chrome Ores and Ferrochrome," read before the Society of Chemical Industry.

Early in 1898 Mr. Saniter went to Port Clarence, and, on behalf of Messrs. Dorman Long & Co. and Bell Brothers, demonstrated the suitability of common Cleveland iron for making high-class basic open-hearth steel. The success of these experiments resulted in the erection of a 200-ton metal mixer, eight 50-ton basic open-hearth furnaces and a rolling mill. The process adopted consisted in using molten Cleveland metal from a mixer and purifying it in the open hearth by a combination of the basic process and the Saniter desulphurizing process.

In June, 1904, Mr. Saniter resigned his position at Port Clarence to become steel expert to Steel, Peech & Tozer, of Sheffield, well-known makers of tires, axles, forgings, springs, etc.

A New Rail Mill The new rail mill of the Republic Iron and Steel Company, at Youngstown, Ohio, is completed. The contract was signed on November 19, 1904, and the first rail was rolled April 22, 1905, being a standard 80-pound section, five months and three days after the contract was signed. This is record-breaking time. The contract called for completion May 1. Some finishing touches have since been put to the equiqment. The mill is a convertible sheet bar and rail mill, with an estimated capacity of 1,500 to 1,800 tons daily. It is erected in connection with the company's Bessemer steel plant, but at present very little steel is available for the new mill, and it is not being operated commercially. The engine, a 54 × 60-inch Corliss, was made by the Filer & Stowell Company, Milwaukee, Wis., and was delivered on board cars ten weeks after the contract was signed. The excavating and foundation work for the mill was done by the Republic Iron and Steel Company, while all the rest of the work, including engineering, was done by the United Engineering and Foundry Company, Pittsburg.

The New Youngstown Bessemer Plant Construction work has started on the new Bessemer steel plant of the Youngstown Sheet and Tube Company, Youngstown, Ohio, and the company hopes to have the plant completed by July 1, 1906. The company has operated a sheet mill, puddling furnaces and a pipe mill for some time. The Bessemer plant will contain two standard 10-ton converters. There will also be a billet and blooming mill, a plate mill and a mill for rolling narrow skelp. Funds are provided by a $2,500,000 bond issue, which is taken by stockholders. The company has one small blast furnace, the Alice, and the bulk of the pig iron required will come from five merchant furnaces near by, whose owners are stockholders in the company and have made a long-term contract by which Bessemer pig iron is to be furnished at two thirds the current market for Bessemer steel billets. This is a new form of relation. Many contracts for the sale of billets have been made, whereby the price of the billets is determined from the current price of pig iron by adding a conversion price, this conversion price increasing as pig iron advances. Very few absolutely new Bessemer steel plants have been erected in the United States in the past ten years. The Youngstown plant of

the Ohio Steel Company was completed in February, 1895, and the Lorain plant of the Johnson Company in April of the same year. Since then the only new Bessemer plant has been that of the International Harvester Company at South Chicago, completed in September, 1903. The Youngstown plant of the Republic Iron and Steel Company, and the Buffalo plant of the Lackawanna Steel Company, while substantially new plants, are based upon older operations.

The McDonald Blast Furnace Charging Apparatus. — A patent was recently granted to Thomas McDonald of Youngstown, Ohio, for a new furnace charging apparatus, in which the

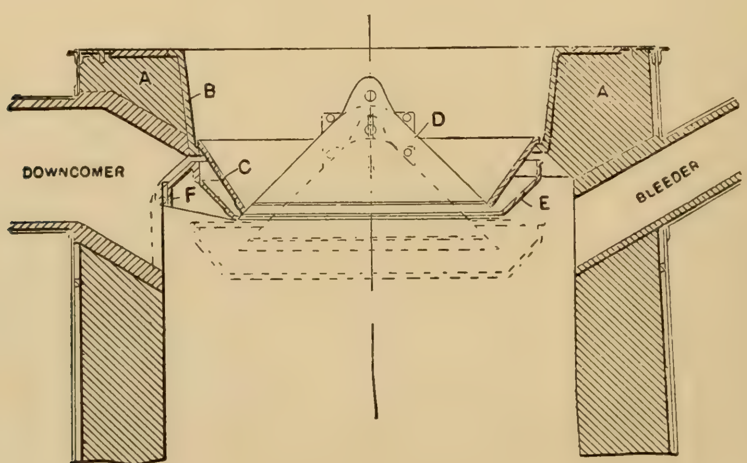


FIG. 1. Vertical Section of a Blast Furnace Top Provided with the McDonald Charging Apparatus

deflector ring for distributing the charge is movable vertically. It has been found that a better distribution of the material and a more uniform working of the furnace can be obtained if the deflector is raised out of action for part of the charge and lowered into operative position for the balance of the charge. In the usual form of distributer the rings are held in a fixed relation to the bell when it is in its lowered position, so that the distributing ring acts upon the dropping charge in the same manner at all times. With the new device the charge may be varied to suit the condition of the furnace, throwing all of the material to the outside or to the inside or a part to the outside and a part to the inside. It is recommended that two charges be dropped

into the furnace with the deflector in its upper position, these being caused to go to the outside of the furnace, forming an annular ridge-shaped heap around the outer portion of the charge. Then, by lowering the deflector, a third charge may

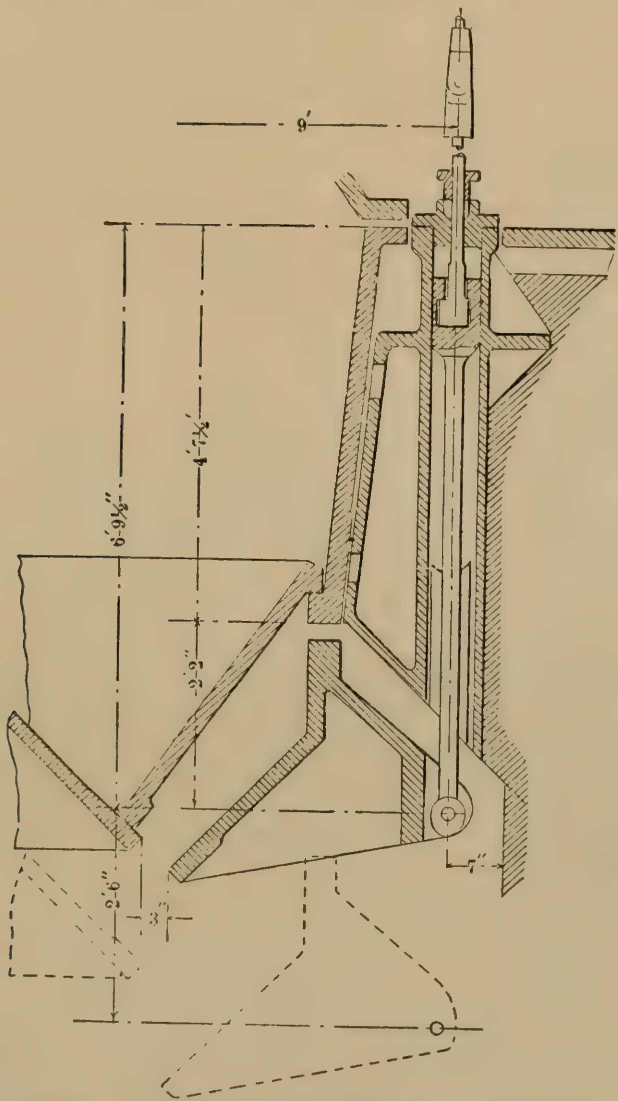


FIG. 2. Sectional Details Showing One of the Lifting Rods

be dropped into the central conical cavity left by the other two charges, and the result is a more nearly uniform distribution.

With the bell arrangement alone or with fixed or stationary deflectors the charge is always thrown in the same place, the fine material piling up close to the wall of the furnace, while the coarse or lumpy material rolls to the center. With Mesabi

ores the furnace soon builds up on the walls and continuous slipping results. It was to overcome this condition that the inventor was led to devise this more flexible means of charging so that changes in the condition of the furnace could be counteracted by changes in the manner of charging.

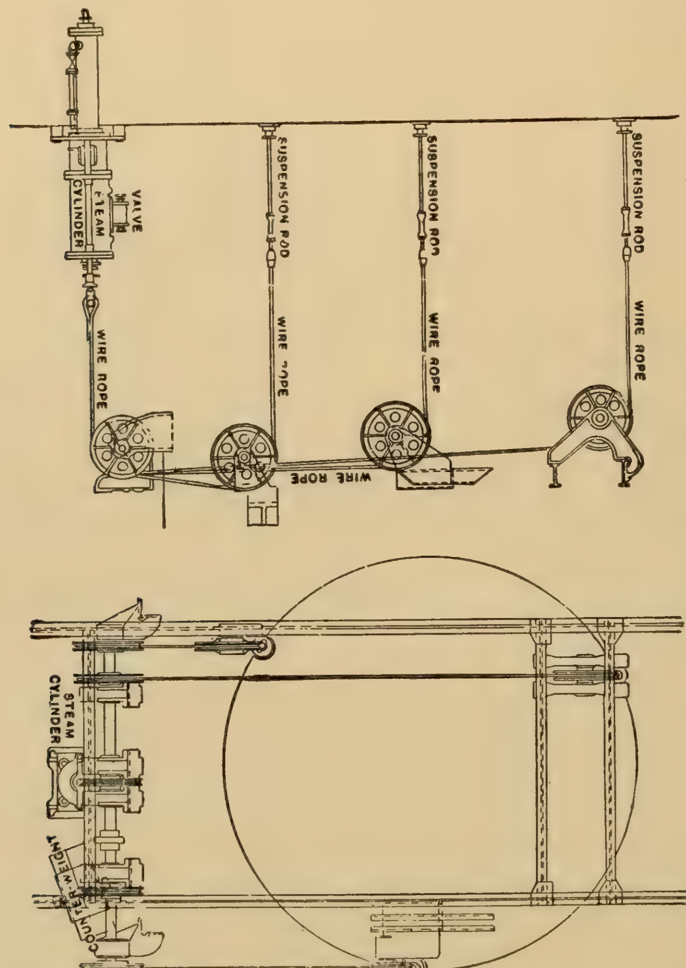


FIG. 3. Plan and Elevation of the Mechanism for Operating the Deflector

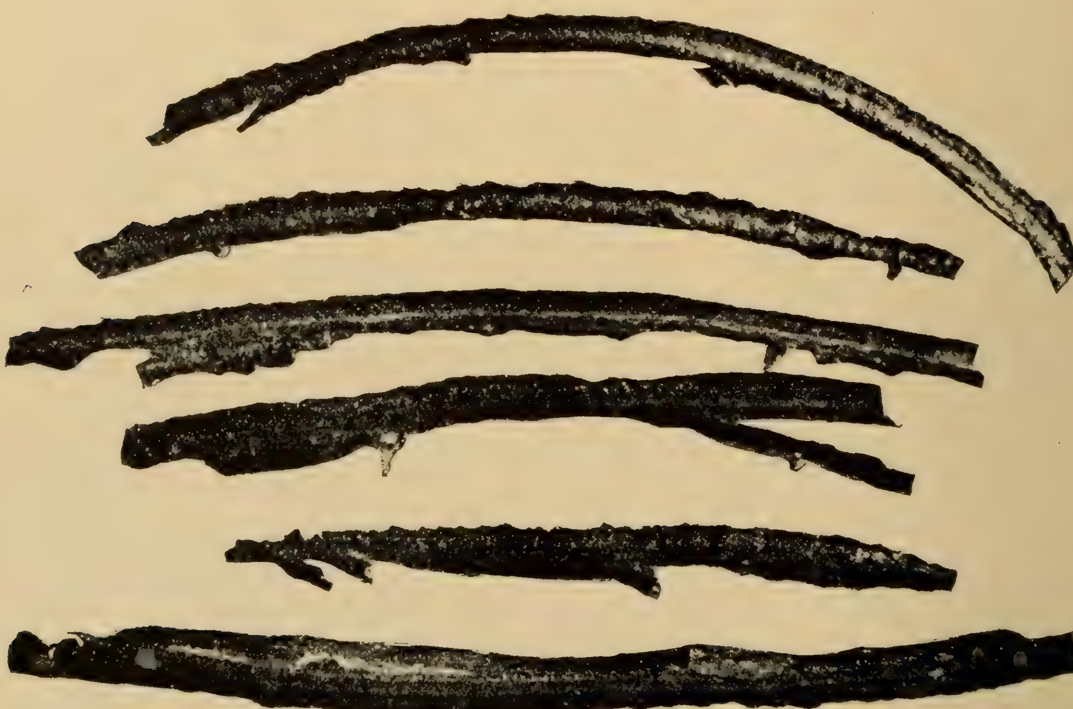
Fig. 1 herewith shows a vertical section of a blast-furnace top provided with the new deflector. A is the wall of the top of a blast furnace having the usual inclined hopper B with the hopper extension C and closed bell D. E is the movable deflector ring shown in its raised and lowered positions. This ring is supported by three rods attached to lugs F placed equidistantly about the circumference of the ring. A detail of one of these

lifter rods and a section through part of the charger is shown in Fig. 2; the solid lines show the bell and deflector in their upper positions and the dotted lines show them in their lower positions. It will be seen that the suspension rod is connected to an enlarged head on the lifter rod by means of a tee head, by the turning of which the parts may be detached. Suitable means in the form of locking blocks are provided to prevent the tee end of the rod from turning after it is in its locked position. The stems of the suspension rods are surrounded with stuffing boxes which prevent the escape of gases.

Fig. 3 gives a plan view and elevation of the mechanism and connections for raising and lowering the deflector ring through the suspension rods. Wire ropes connecting with the suspension rods pass over pulleys and connect with sheaves to a shaft which is rotated by a fourth sheave connected to a steam cylinder. The valve controlling this cylinder has rope connections leading to the operating floor, so that the valve may be shifted and the deflector moved to either of its positions from that point. "The Iron Age," March 16, 1905.

Shavings Cut from Rails by Wheel Flanges. — That long shavings can be cut from the head of the outer rail on a sharp curve by the wheel flanges of a switching engine and also by the wheel flanges of a slued truck under a heavily loaded car, seems new although it may not be new to some readers of this paper. A certain amount of rail wear on sharp curves under heavy traffic is always to be expected, but an example of cutting, not merely abrasion and wear, is unusual. Mr. Samuel Rockwell, assistant chief engineer of the Lake Shore, has brought to our attention such an example. In the yard of the Lake Shore at Ashtabula Harbor, Ohio, is a 16°-curve which carries a heavy traffic of 100,000 pound cars loaded with coal and iron ore, and most of the switching is done with six-wheel switching engines weighing 130,700 pounds, and having a wheel base of 11 feet, 3 inches. These engines when passing around this curve cut long, thin shavings from the inside of the head of the outer rail and soon wear it away until it has to be removed. The engines are all quite new and the tires are in good condition without sharp flanges. The accompanying illustration, from a photograph of a number of these chips or shavings furnished by Mr. Rockwell,

shows their exact size and appearance. They are from 3 inches to 5 inches long, and from $\frac{1}{8}$ inch to $\frac{1}{4}$ inch wide, and are curved like a machine tool chip. The outer face is bright and worn quite smooth, while the rear face is dull and shows the grain of the metal where it has been torn away from the head of the rail. At the bottom edge the chips are about one thirty-second inch thick and are rough and jagged. The thickness tapers to a serrated knife edge at the top, and for a depth of about one-sixteenth inch this edge is tempered a deep blue by the action of the heat



[Shavings Cut from Outer Rail on 16° Curve
(Scale exact size)

generated in tearing away the chip. This temper color is clearly shown in the two upper specimens in the illustration.

On this same curve and also in a yard on the Vandalia similar chips have been cut by wheel flanges under heavily loaded cars, but they are only about one quarter as heavy as those cut by the engines. In one case on the Vandalia, some new Pennsylvania 100,000-pound cars cut the rails on a sharp curve, and on investigation it was found that the drawbars did not have sufficient lateral motion, and the free movement of the trucks was restricted, thereby causing the wheels to bear against the rail

with excessive pressure. Careful observation in the Ashtabula yard showed that quite often in the case of high capacity cars, fully loaded, the car body cants to one side on entering the curve before the truck has had time to assume a radial position and the pressure on the side bearings holds the wheel flanges against the rail hard enough to start the cutting.

It does not seem reasonable that the cutting of the rails is due entirely to the action of the wheel flanges in the case of the six-wheel switch engines at Ashtabula. The tires on these engines were new, and a new tire is as unlike a cutting tool as it is possible to imagine. The form of the tread and flange is determined with the one object of preventing such action. From observation of rails laid on tangents and subjected to heavy loads it is known that the pressure of the treads breaks down the structure of the metal and squeezes it out to the sides, usually the inner side, forming a lip or burr. This indicates the presence of vertical or slightly inclined cleavage planes in the metal where the cells have been forced apart and have slid over one another. Exactly the same action takes place on a curve where the rails carry heavy loads, and the appearance of the chips cut off seems to confirm the assumption. They have been forced down and broken off in vertical cleavage planes, not curled out from the side of the rail head as would be the case if the wheel flange acted as a true cutting tool. The inside surface of the rail head being rough and the curve sharp, there would be a natural tendency for even a new flange to climb the outer rail slightly and thus break off the chips which were previously loosened from the body of the metal by the vertical pressures of the wheel treads. A new rail would probably not show the effects of the heavy wheel loads until some time after it had been put in the track, but as soon as the breakdown began to take place the cutting could be expected to occur.

The subject is an interesting one, and we should be glad to have information from others who have had experience with it. "The Railroad Gazette," April 14, 1905.

The Structure of Iron. — Much consideration has been given of late to the structure of steel, and many propositions are advanced as more or less novel by men of the present generation who have not made themselves acquainted with the work done,

the information obtained and the theories held by their predecessors in this important field of engineering. A reference to the pages of the second edition of "Experiments on Iron and Steel," by the late David Kirkaldy, published in 1863, will serve to show that very much more was known forty years ago than is supposed; while puzzles and problems freely discussed then are apparently no nearer solution now.

As, after all, commercial steel is but a form of iron, or iron a variety of steel, it may not be without profit to inquire into our existing knowledge about the structure of wrought iron in the shape of bars or plates or rails or shafts. The inquiry will be found to result in an admission of ignorance rather than in the assertion that all is known that need be known. Let it be admitted that an iron bar can be so broken that it will show either a fibrous or a crystalline fracture; what are we to deduce from the fact, or brace of facts? Are we to assume that all iron is crystalline, but that when slowly broken the crystals are drawn out into fibers? or is it the fact that all iron is fibrous, but that when broken suddenly such a change takes place that fibers are converted instantly into crystals? Whichever theory we adopt we find it unsatisfactory. On the one hand, we have a proposition that there is no such thing made and sold as fibrous iron; that, indeed, fiber cannot be obtained by any method of manufacture, and can only exist in metal which has undergone stresses which exceed the elastic limit of the material. On the other hand, we have the apparently equally untenable view that the amorphous, or totally non-crystalline metal, will suddenly — precisely at the plane of cleavage and nowhere else in the bar — develop a beautiful crystalline structure. No case can be mentioned, we think, apart from metals in which crystallization can take place suddenly in a solid. Shafts and railway axles and tires have been condemned over and over again after disastrous failures, on the ground that the metal was crystalline when it ought to have been fibrous; and yet the crystal was developed at the moment of fracture, or else there is no such thing to be had as truly fibrous bars or plates or tires or axles.

The general facts were more or less known long before 1863, but it remained for Kirkaldy to collect scattered information, add to it, and establish a fine reputation almost in a moment by the publication of his book. We shall give here a few quotations

from the utterances of men full of authority with which the book abounds. Mr. Clay, of the Mersey Forge, said, "It seems that all wrought iron is more or less crystalline in its structure, and that the difference between what we call crystalline and fibrous iron only consists in the fineness of the crystals. . . . It is known that a piece of good fibrous iron will break under a smith's hammer with a long silky appearance; if suddenly fractured by an irresistible blow the same bar will break crystalline, but the crystals will be very fine and close and of a good color." Mr. McConnell, in the course of a discussion before the Institution of Civil Engineers in 1850, said, "Whenever iron is subjected to a jar the fracture is square across and crystalline." Robert Stephenson, at the same meeting, advanced the curious theory that what appeared to be crystals are not really crystals at all. "In a piece of iron with large facets which appeared extremely crystalline, when one of the crystals was examined under a microscope, it gave much the same appearance as a fibrous surface gives to the naked eye; in fact, it would appear to consist of bundles of fibers broken through at certain angles." Mr. Kirkaldy, summing up the results of his experiments, says, "Iron when fractured suddenly presents invariably a crystalline appearance; when fractured slowly its appearance is invariably fibrous. The appearance may be changed from fibrous to crystalline by merely altering the shape of the specimen so as to make it more liable to snap." Of steel, he says, "Steel invariably presents when fractured slowly a silky, fibrous appearance; when fractured suddenly the appearance is invariably granular, in which case also the fracture is always at right angles to the length." We seem to hear the echo of all this almost daily now.

If it be true that steel behaves like iron, the fact ought to be kept steadily in mind, because of its bearing on the quality of material which fails. The real question at issue is this, Is all steel under all circumstances crystalline until the crystals are drawn out mechanically by some method of traction, time being allowed? As we have already said, it is equally difficult to receive or reject this theory. Kirkaldy lays very great stress on the time factor. Recently we had occasion to refer to Mr. Hopkinson's experiments on the effect of sudden stress on wires. He found, it will be remembered, that provided the duration of

the effort did not exceed one one-thousandth of a second the wire would stand more than the normal breaking stress. But Kirkaldy found that bars suddenly stressed broke with 80 or 90 per cent of the stresses they would endure slowly applied. At the present moment the pressing need is a close definition of the words "crystalline" and "fibrous." It is almost incredible that any sudden stress can produce in a rigid metal like steel a true crystalline texture which it did not possess before. It is much more easy to believe that a crystalline structure can undergo deformation by internal molecular sliding, and so become fibrous. If, however, this is true, then a crystalline fracture in a broken shaft cannot be regarded as evidence of bad metal. Forty years ago the theory that shafts broke because they became crystallized by vibration was stoutly advocated, and as stoutly repudiated. If it can be shown that in point of fact a shaft must necessarily be crystalline, then much that has been written about the fatigue of metals falls flat. The steel gives way because it is fatigued, not because it is crystalline, and a new explanation of the fatigue of iron and steel will have to be sought. "The Engineer" (London), March 24, 1905.

A New Alloy for Making Steel Castings. — In a recent issue we gave a brief account of Dartium alloy, for which exceptional qualities are claimed. We have now secured some fuller details. Dartium alloy is the invention of Mr. James W. Chenall, and enables the ordinary iron founder to manufacture steel castings as promptly as brass castings. Machine shops can make their own tool steel from scrap, and it is claimed that cast iron can be greatly improved in strength and elasticity. Malleable cast-iron castings as well can be made equal in tensile strength to ordinary mild steel. The cost of the alloy is reasonable, and "Dartium steel castings" are being made at several foundries in the Midlands and the West of England.

Below are the results of several tests, illustrating the value of the alloy for various purposes.

Dartium Mild Steel Castings made from Mild Steel Scrap. — Tests made at the Brunswick Testing House, Wednesbury, belonging to the Patent Shaft and Axletree Company, Limited, showed that the average breaking tensile strain of eight bars tested was 27.2 tons to the square inch.

Iron Castings with Dartium Alloy Added. — The original cast iron had a breaking tensile strain of 4.9 tons to the square inch. With Dartium added, No. 1 bar showed 9.5 tons to the square inch; No. 2 bar showed 6.4 tons to the square inch; No. 3 bar showed 7.3 tons to the square inch; and No. 4 bar showed 6.1 tons to the square inch. Transverse test with the usual standard bar gave a breaking load of 3,800 to 3,900 pounds. Tests made at Messrs. Robey's works, Lincoln, showed an increase of about 200 pounds on transverse breaking load.

Malleable Cast-Iron Castings with Dartium Added. — Tests made at the Sheffield Testing House, Sheffield, showed that malleable cast iron, with an original breaking tensile strain of 18.91 tons to the square inch, with Dartium added gave 25.19 tons to the square inch.

The alloy is manufactured in qualities suitable for various purposes, viz.:

The manufacture of Dartium malleable steel castings.

Ordinary and high quality tool steel.

The increase of the tensile strain of malleable cast iron castings and of ordinary cast iron.

In the manufacture of Dartium steel castings the quantity of carbon in the scrap employed governs the quantity of Dartium alloy required. When Bessemer or open-hearth scrap containing, say, from 0.45 per cent to 0.50 per cent of carbon is utilized, then the quantity of Dartium alloy required will be from 5.0 per cent to 7.5 per cent. If the stock used be lower in carbon a larger quantity of Dartium alloy must be employed; for instance, if open-hearth very mild steel, containing under 0.20 per cent carbon be the stock, then from 10 per cent to 15 per cent of Dartium alloy must be used. In the production of high quality tool steel, open-hearth mild steel having low percentages of carbon and manganese should be employed, such as is used in the manufacture of boiler plates. A steel made from good quality mild steel scrap (boiler plate) with from 15 to 25 per cent Dartium alloy, will, it is said, take any degree of hardness in tempering (tempering by quenching), and while the cutting edge may be exceedingly hard, the body of the tool from near to the point will remain soft and ductile.

For increasing the tensile strength and elasticity of cast iron, from 3 to 5 per cent of the alloy gives very satisfactory

results, greatly increasing the elasticity of the cast iron, and increasing the strength 15 to 20 per cent. In special cases as high as 10 per cent may be used to advantage. This alloy is being used by many iron and steel founders with considerable advantage. Several firms in the Midlands are erecting suitable furnaces, and a number are putting blast under existing brass furnaces to enable them to make small steel castings and tool steel. We give the above details on the authority of Messrs. J. H. Hackworth & Co., of 46 Queen Victoria Street, E. C., the sole agents for London and district and export. "Iron and Coal Trades Review," April 7, 1905.

A Plant for Clinkering Flue Dust. — A project is on foot and has assumed practical shape for the utilization of the large quantities of flue dust that have been accumulating in recent years at the blast furnaces using the finer Mesabi ores in greater or less quantities. The proposal is now made by Hoover & Mason, of Chicago, who have developed the ore unloading machinery bearing their name, to take this flue dust, convert it into clinker by a process of their own and deliver it again to the furnaceman in a form that will make it readily reducible. Hoover & Mason expect to build a plant in the Mahoning Valley at some convenient point, and to handle at this central plant all the flue dust shipped from the furnaces in the two valleys with which they have made arrangements. Thus far contracts have been made to agglomerate the flue dust accumulated at the Mabel, Claire and Alice furnaces at Sharpsville, Pa.; the Ella furnace at West Middlesex, Pa.; the Stewart furnace at Sharon, Pa., and the two Hubbard furnaces at Hubbard, Ohio. It is probable that the Hoover & Mason plant, on which, as well as the process, patents have been taken out, will be erected at Hubbard. It is understood that powdered coal is used in the clinkering of the fine ore, which comes from the apparatus in a form quite desirable for furnace use.

The arrangement with the furnace companies stipulates that the flue dust is to be hauled from their furnaces to the central plant and the ore clinker returned free of cost to them, they to pay for the ore at a certain stipulated amount below the cost of lumpy Lake ores of like analysis delivered at furnace. This fixed differential, which is an advantageous one to the furnaces,

represents, therefore, the value which the new process imparts to what in its present state is a worthless refuse product of furnace operations. From time to time attempts have been made to utilize a certain percentage of flue dust, wetting it up and charging it in small quantities along with lumpy ore; but between the lessening of output and the blowing over again of a certain part of the fine stuff after the furnace heat has expelled its moisture, the results have not been at all satisfactory.

The possibility of clinkering dusty ores at the mine and shipping them in a lumpy form is a subject that will no doubt have consideration if the new process is a success. More attention has been given than ever in the past year to the question of treating fine ores, particularly flue dust, so that the waste that has been constant since Mesabi ores have been used in considerable quantities, may be avoided. In the fall of 1904 a working test was made at the Isabella furnaces, Sharpsburg, Pa., of the Brown down-draft furnace for the clinkering of flue dust. The apparatus was designed by Horace F. Brown, M. E. These tests demonstrated that flue dust can be economically converted to clinker without the addition of any flux, and that by adding a certain percentage of lime a saving in fuel can be made. "Iron Trade Review," April 6, 1905.

The Blast-Furnace Gas Engine Station of the John Cockerill Company. — There has been recently erected at the Cockerill establishment at Seraing a new electric central station with gas engines operated with gas from the blast furnaces. The station has a capacity of 3,300 electrical horse-power. The distribution consists of two 250-volt circuits for the transmission of power and four 126-volts lighting circuits, all continuous current. Two units of 200 horse-power each furnish triphase current for operating the mills by which cement is made from the slag. The new station is equipped with three engines. The first is a double-acting four-cycle tandem of 1,500 horse-power, running at 100 revolutions per minute; the diameter is 39.37 inches and the stroke 47.63 inches. The two others are single-acting four-cycle tandems of 700 horse-power each; diameter 35.43 inches and the stroke 39.37 inches; the speed, 139 revolutions per minute. The energy is consumed by 5,000 incandescent and 550 arc lamps and 150 motors of from 100 to 250 volts power each. A view of this

station was shown in the March issue on page 134. "Power," April, 1905.

First Award of the John Fritz Medal. — Lord Kelvin, now in his eighty-first year, has been selected as the first recipient of the John Fritz medal, for his "Cable Telegraphy and Other General Scientific Achievements."

Obverse and Reverse Sides of the John Fritz Gold Medal

Carnegie Research Scholarship. — At the annual meeting of the Iron and Steel Institute held in London, May 11, 1905, a Carnegie Research Scholarship of $500 was awarded to Henry Cook Boynton, instructor in metallurgy and metallography in Harvard University. Mr. Boynton is the third American to be successful in obtaining this highly praised scholarship, two Columbia University men having previously won it. Mr. Boynton was born in Plymouth thirty years ago and was educated in the schools of that town, graduating from the high school in 1896, and entering Harvard University the same year. He received his A.B. degree in 1900, his S.M. degree in 1901 and his S.D. degree in 1904. His thesis for the doctor's degree dealt with the "Relation between the Treatment, Structure and Properties of Steel." Since his graduation Mr. Boynton has devoted much time to research work, dealing chiefly with the metallography of iron and steel, and has written several papers on the subject. The present scholarship will make possible a more vigorous prosecution of his investigations in the metallurgical laboratory of Harvard University.

We see in this award another indication of the growth and strength of the Department of Mining and Metallurgy of Harvard University, which, established but some ten years ago, has so rapidly assumed a leading position among mining schools. Its reputation is firmly established and its graduates have given such good account of themselves in the practice of their profession that they are eagerly sought, the department having received this year some thirty applications in excess of the number of students in the graduating class.

International Congress. — An International Congress of Mining, Metallurgy, Mechanics and Applied Geology will be held at Liége from the 26th of June to the 1st of July, 1905, in connection with the Universal Exhibition. It is convened under the patronage of the government, and organized by the Union of Collieries, Mines and Ironworks in the Province of Liége, and by the Liége Engineers' Association (Association des Ingénieurs sortis de l'Ecole de Liége).

The complete text of the questions set down for discussion, the regulations of the congress and the complete list of the members of the organizing committee, may be obtained on application to the general secretary, 16, Quai de l'Université, Liége.

The Metallurgical Section will discuss the following questions: (1) Utilization ot non-caking coals for making coke; (2) study of the blast furnace; (3) influence of foreign substances on pig irons and steels; (4) methods for intercepting dust from blast-furnace gases, with a view to their utilization; (5) slag bricks and cements; (6) utilization of poor gases, with a view to producing power for driving roll-trains; (7) new methods for making open-hearth steel; (8) special steels; (9) forging by the press and steam hammer, hardening and annealing; (10) electro-metallurgy; (11) metallography.

REVIEW OF THE IRON AND STEEL MARKET

The rather noticeable absence of fresh buying of pig iron and finished steel products commented on a month ago has become more marked, and the present condition in the iron and steel market as a whole is one of pronounced dullness in the matter of new business, and of continuance of the previous great activity in the matter of production.

The halt in buying is the effect of perfectly natural causes. Last fall prices were decidedly low, and it required no great amount of confidence on the part of buyers to prompt them to contract liberally. Their tendency was encouraged by the liberal policy of the leading interest, followed at a distance by other producers, in permitting them to contract far ahead at the then existing prices. As soon as the buying movement was well started it acted to enhance confidence, and new buying proceeded at a greater pace. Then some price advances were made and there was further buying, after which prices of finished products were advanced to the present level. As substantially all buyers were covered before the last advances, there has been very little buying at the present level, although this has been maintained now for approximately three months. The contracts made have not expired, and specifications against them permit a continuance of activity at the mills. In a few lines the contracts are beginning to expire, while in others they extend for several months yet, and there is no reason to assume that specifications in such lines will not continue heavy clear through the summer.

It can hardly be said that production is yet showing any material decline. Where the tonnage in some light lines may have fallen off a trifle, the tonnage is greater in certain heavy lines, particularly structural shapes and plates. The grand total, however, seems to have about reached its maximum. The May production of pig iron may be estimated at very close to 2,000,000 tons, with very few furnaces scheduled for resump-

tion in the next few months, several stacks just blown out, and others to follow, on account of the necessity of relining. It has been commented on several times lately that the current production of pig iron has been at a rate which could not be maintained indefinitely, the percentage of capacity out being less than must normally be the case for relining and repairs. The dullness of last summer afforded an unusual opportunity to anticipate such work, making possible a brief spurt above the normal. It also appears to be the case that furnaces have been pushed harder than usual of late, so that linings will not last as long as usual. One furnace has just blown out after having made less than a quarter of a million tons on its lining in less than a year and eight months, against a record of over a million and a quarter tons in seven years and four months.

For a time it may be that the reduction in pig iron production from physical causes will approximately balance the decreased demand which is gradually materializing, but by the end of summer a voluntary curtailment seems to be in order. Still, there is no question whatever that the total production of both pig iron and finished products this year will greatly exceed all previous records.

Pig Iron. — The United States Steel Corporation has not bought any pig iron for May delivery. It had made monthly purchases of from 25,000 to 40,000 tons for each month beginning with last December. Whether it will buy for June delivery is problematical at this writing. The pig iron market is easier, and was easier before the decision of the steel corporation was reached, as noted in our last report. Since then there has been a decline of from 25 to 50 cents a ton in all markets. The Cambria Steel Company early in May bought 30,000 tons of Bessemer, with option of part basic, for May, June and July delivery, the price being nominally \$15.50 valley, or \$16.80 delivered Johnstown, subject to adjustment should the market decline. Otherwise there has been very little buying in any district. Several of the southern furnaces are willing to do business at \$13, Birmingham, for No. 2, showing a reduction of 50 cents from the price which has been maintained since last December after the phenomenal buying movement and sharp advance in prices which occurred in the last quarter of last year. Northern furnaces in the Chicago district have made a corresponding re-

duction, as they are under the necessity of maintaining a parity with Alabama. In the Pittsburg market the furnace situation is very much mixed. A number of furnaces, well sold up in July, have refused to make any concessions on foundry or forge, while others appear willing to shade former prices by 50 cents a ton, making No. 2 $16.35, delivered Pittsburg. In Bessemer pig there are hopes of artificial maintenance of prices, so that nominally, at least, the furnaces have not reduced their prices, while in basic the production has been rather short, and this has sustained the basic market. In the east there has been no more business than elsewhere, and the eastern furnaces have made only a slight reduction from previous asking prices. In all markets there is a question what would result from the appearance of a well-defined demand. This might stimulate the market, or might result in lower prices, since it is the well-known policy of many furnaces not to reduce asking prices until there is a good chance of obtaining orders by so doing. We now quote asking prices as follows: F.o.b. valley furnace: Bessemer and basic, $15.25 to $15.50; No. 2 foundry, $15.50 to $16.00; gray forge, $14.50 to $15.00. Delivered Pittsburg: Bessemer and basic, $16.10 to $16.35; No. 2 foundry, $16.35 to $16.85; gray forge, $15.35 to $15.85. F.o.b. Birmingham: No. 2 foundry, $13.00 to $13.25; gray forge, $12.00 to $12.25. Delivered Philadelphia: No. 2 X foundry, $17.00 to $17.50; standard gray forge, $15.50 to $15.75. Delivered Chicago: Northern No. 2 foundry, $17.00 to $17.25; malleable Bessemer, $17.50. Freight Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65.

Steel. — Deliveries of billets and sheet bars are now quite satisfactory, and prices are easier, particularly for later delivery. At the moment, transactions are very light. We quote ordinary soft steel billets at $23.00 to $23.50 for Bessemer and $23.50 to $24.00 for open-hearth; sheet bars, $25.50 to $26.50; wire rods, $34.00, all f.o.b. Pittsburg, for early delivery. On deliveries extending over the second half of the year some concessions might be obtained from these prices.

Shapes. — There continues to be good booking of structural contracts, so that fabricating concerns are specifying very freely with the shape mills, and the latter have full operation assured all through the summer. These specifications are, of

course, all on old contracts, at lower than present prices, which we quote unchanged as follows, carloads and larger lots, f.o.b. Pittsburg: Beams and channels, 3-inch to 15-inch inclusive, angles 2 x 3 to 6 x 6 inclusive, and zees, 1.60 cents per pound; tees, 3-inch and larger, 1.65 cents; beams and channels over 15-inch, 1.70 cents.

Plates. — Specifications on old contracts continue excellent, the leading mills having such specifications already in hand for several months' run, while further specifications on old contracts are certain, so that the leading mills are assured of business almost to the end of the year. The steel car plants are, of course, the largest customers, having still unfilled orders for many cars, which will keep their plants busy for six months or more. The smaller mills, which did not sell so far ahead when prices were lower than at present, have less business ahead, and are abandoning their efforts to secure premiums on prompt shipment of new business. We quote the regular prices unchanged, based on 1.50 cents for plates $6\frac{1}{4}$ to 14 inches wide, inclusive, and 1.60 cents for wider plates, subject to extras for plates under $\frac{1}{4}$ inch thick, over 100 inches wide, and for special qualities.

Merchant Bars. — Some contracts for merchant steel bars, taken last fall at 1.30 cents, expire on July 1, and the buyers recently made some inquiries for second half. The mills were disposed to make some concession from the present official price of 1.50 cents, Pittsburg, to such large buyers, but the inquiries seem to have been withdrawn, and it develops that while the contracts expire July 1, the buyers have been taking a much larger tonnage than their current consumption with a view to accumulating stocks. Other contracts, taken at 1.40 cents, run for the rest of this year, and even into next year. New business is very small. In iron bars the market has declined further, with little business doing, and are now quoted at 1.60 to 1.65 cents, Pittsburg, and 1.50 to 1.55 cents, Chicago.

Sheets. — The whole sheet market is full of contracts made at the low prices, so that it is very difficult for mills to make fresh sales. The official price of 2.40 cents on No. 28 black is regularly shaded by \$1.00 to \$2.00 per ton. Galvanized sheets are fairly firm at 3.45 cents, for No. 28. Official prices on corrugated roofing remain at \$1.75 per square for painted and \$2.95

for galvanized, No. 28 gauge; but painted is being shaded 10 cents a square and galvanized 5 cents a square on desirable business.

Scrap. — Following the weakness noted a month ago, the whole market has become demoralized, and there is no buying by consumers. Occasional sales are made between dealers at from \$1.00 to \$2.00 per ton less than previously quoted. In Chicago the decline has been even greater. For the present, prices cannot be accurately quoted.

STATISTICS

British Iron and Steel Production.* — The figures published heretofore of British iron output have been approximate only. We have now the full statement for the year 1904, as reported by the British Iron Trade Association. The pig iron made last year was 8,562,658 long tons, which is a decrease of 248,546 tons, or 2.8 per cent, from 1903; but an increase of 44,965 tons, or 0.5 per cent, as compared with 1902. Apparently the pig iron production has reached a point where large fluctuations are not to be expected. Nearly two fifths of this iron was made with imported ore. The production of iron ore in Great Britain — lacking only a small quantity taken from quarries or shallow pits — was 9,161,588 tons, while the imports were 6,100,556 tons. The proportion of iron made from foreign ore is probably a little greater than that indicated by these figures, since the imported ore is usually rather richer in iron than that mined at home. Spain continues the mainstay of the British ironmasters. Last year the Spanish ore was 4,648,335 tons, or 76.2 per cent of the total imports. The average consumption of ore was 1.78 tons per ton of iron made.

With an average of 325 furnaces in blast last year, the output per furnace was 26,346 tons. The highest average was 43,577 tons per furnace, which was the result in the Lancashire district; the lowest was 13,294 tons, in Derbyshire. The Scotch furnaces also showed a low average — 15,670 tons yearly.

The steel production for two years has been as follows, in long tons:

	1903	1904
Bessemer	1,910,018	1,781,533
Open-hearth	3,124,083	3,245,346
Total	5,034,101	5,026,879

The total output was almost the same in both years, the decrease in 1904 being only 7,222 tons, or a little over 0.1 per cent. This was made up by a decrease of 128,485 tons, or 6.7

* "Engineering and Mining Journal," March 30, 1905.

per cent, in Bessemer, and an increase of 121,263 tons, or 3.9 per cent, in open-hearth steel. The open-hearth furnace holds its own, and more, with British steel-makers. Last year open-hearth steel was 64.5 per cent of the total. The average output of Bessemer steel per converter in use was 35,630 tons for the year, while the result from the open-hearth furnaces was 9,400 tons.

The basic process, which is confined to open-hearth work in this country, is applied to the converter in Great Britain to a considerable extent. The division of steel into acid and basic in 1904 was as follows:

	Acid	Basic	Total
Bessemer	1,129,224	652,309	1,781,533
Open-hearth	2,583,282	662,064	3,245,346
Total	3,712,506	1,314,373	5,026,879

The basic open-hearth process has made less impression in Great Britain than in this country, as shown by the figures. The proportion of acid steel last year was 73.8 per cent of the total.

The output of wrought, or puddled, iron has not yet been ascertained. The stationary make of steel, with a decline in the pig iron, indicates that there was no increase, but probably a decrease, in the wrought iron. The ratio of steel to pig-iron production, which was 57.1 in 1903, increased to 58.7 in 1904. In the United States this ratio was 84.1 last year.

German Iron Production. — The output of the German blast furnaces in the month of January is reported by the German Iron and Steel Union as below, in metric tons:

	1904	1905	Changes
Foundry iron	159,155	147,878	D. 11,277
Forge iron	63,173	60,602	D. 2,571
Steel pig	52,862	51,303	D. 1,559
Bessemer pig	41,916	31,805	D. 10,111
Thomas pig	513,947	474,621	D. 39,326
Total	831,053	766,209	D. 64,844

The total decrease was 7.8 per cent; all kinds of iron show lighter output this year. The decrease was most marked in Bessemer and in Thomas, or basic, pig. Steel pig, in the German classification, includes spiegeleisen, ferromanganese, ferro-

silicon and all similar alloys. Some of the decrease was probably due to the coal strike and consequent short supplies of fuel for the blast furnaces.

The report of the German Iron and Steel Union shows that the production of pig iron in February was 672,473 tons, being 93,736 tons less than in January. For the two months ending February 28 the production was as follows, in metric tons:

	1904	1905	Changes
Foundry iron	295,540	267,936	D. 27,604
Forge iron	134,325	112,783	D. 21,542
Steel pig	90,690	96,104	I. 5,414
Bessemer pig	80,490	50,188	D. 30,302
Thomas pig	1,010,468	911,671	D. 98,797
Totals	1,611,513	1,438,682	D.172,831

Steel pig, in the German classification, includes spiegeleisen, ferromanganese, ferrosilicon, and all similar alloys. This steel pig was the only class showing an increase; in all others there was a falling off. The decrease was 10.8 per cent in Thomas or basic pig, and 10.7 per cent in the total output. The smaller production this year was largely due to the strike of the coal miners. "Engineering and Mining Journal," March 30 and April 27, 1905.

Iron Production in France. — The preliminary returns of iron production in France in 1904 show that the output of the blast furnaces was: Foundry iron, 553,715 metric tons; forge and steel pig, 2,446,072 tons; total, 2,999,787 tons, an increase of 159,270 tons, or 5.6 per cent over the preceding year.

The production of wrought, or puddled, iron was 554,632 metric tons, of which 33,932 tons were sheets and 520,700 tons bars, shapes and other forms. The total showed a decrease of 44,278 tons, or 7.4 per cent, as compared with 1903.

The production of steel ingots for the year was 2,080,354 metric tons, an increase of 240,726 tons, or 13.1 per cent. This includes both Bessemer and open-hearth ingots. The output of finished steel compares as follows:

	1903	1904	Changes
Rails	229,071	246,339	I. 17,268
Sheets and plates	292,544	299,376	I. 6,832
Other forms	784,094	936,993	I.152,899
Total	1,305,709	1,482,708	I.176,999

The production of converter and open-hearth steel is not reported separately. The ratio of steel to pig-iron production was 69.3 in 1904, against 64.8 in the preceding year. "Engineering and Mining Journal," April 20, 1905.

Belgian Iron Production. — The output of the Belgian blast furnaces in February was 95,943 metric tons of pig iron. For the two months ending February 28, the production was 208,763 tons, against 221,297 tons in the corresponding period of 1903, a decrease of 12,534 tons. On March 1 there were 33 furnaces in blast. "Engineering and Mining Journal," April 27, 1905.

RECENT PUBLICATIONS

Ausfuhrliches Handbuch der Eisenhuttenkunde. Dritter Band: Die Gewinnung des Eisens Aus den Erzen, by Dr. Hermann Wedding. 662 6 × 9-in. pages; 332 illustrations. Fridrich Vieweg & Son. Braunschweig. 1904. Price in Germany, 28 marks. — This is the third part of Dr. Wedding's treatise on the metallurgy of iron. It deals with the extraction of iron from its ore. The treatment is exhaustive and is probably the most accurate and complete history of the development of the blast furnace from its origin ever written. The book is printed in two volumes with paper covers. It is beautifully illustrated and printed on excellent paper.

Suction Gas, by Oswald H. Haensagen. 86 5 × 7-in. pages. The Gas Engine Publishing Company. Cincinnati. Price, $1.00. — The suction producer originated in Europe under the stimulus of a greater need for fuel economy, but it is now being introduced in America, where it has aroused the interest of many fuel consumers. This little book is, therefore, a timely one, giving as it does, in a clear and satisfactory manner, the required information with regard to the principles, economy and working of this new and promising type of gas producer.

A Treatise on Concrete, Plain and Reinforced, by Frederick W. Taylor, vice-president of the American Society of Mechanical Engineers, and Sanford E. Thompson, associate member American Society of Civil Engineers. 585 6 × 9-in. pages; 176 illustrations. John Wiley & Sons. New York. 1905. Price, $5.00. — This treatise is designed for practicing engineers and contractors, and also for a text and reference book on concrete for engineering students. It includes chapters by R. Feret, an authority on the effect of sea water; William B. Fuller, a well-known concrete expert; and Spencer B. Newberry, an expert on the chemistry of hydraulic cement. The following table of contents indicates the scope and exhaustiveness of the book:

"Concrete Data. Elementary Outline of the Process of Concreting. Specifications. Choice of Cement. Classification of Cements. Chemistry of Hydraulic Cements (by Spencer B. Newberry). Standard Cement Tests. Special Tests. Strength of Mortars. Selection of Sand. Voids in Sand and Stone. Proportioning Concrete by Mechanical Analysis (by William B. Fuller). Formulas for Volumes. Tables of Materials per Cubic Yard of Concrete. Tables of Volumes of Concrete per Barrel of Cement. Strength of Concrete. Growth in Strength. Consistency. Gravel *vs.* Broken Stone. Cinder Concrete. Concrete Specimens for Testing. Adhesion of Concrete to Steel. Theory of Reinforcement. Design of Reinforced Members. Tables of Dimensions and Reinforcement. Tests of Reinforced Concrete. Mixing Concrete. Depositing. Laying in Freezing Weather. Fire Resistance. Durability. Impermeability. Waterproofing. Effect of Sea Water (by R. Feret). Effect of Addition of Lime, Clay, etc. Sidewalks. Basement Floors. Building Construction. Foundations. Concrete Piles. Piers. Dams. Retaining Walls. Arches. Tunnels. Reservoirs. Tanks. Patented Systems. The Manufacture of Cement. References to Literature. Appendix. Indexes."

The authors of this book are to be congratulated upon the production of so excellent and valuable a work, and are entitled to the gratitude of the engineering profession.

A very good photographic view of the Harvard Stadium is reproduced as a frontispiece.

The carefully prepared and classified references to concrete literature form a very valuable feature of the book.

The typography, printing and binding are excellent, but we doubt that the many pages of advertising matter placed at the end increase its attractiveness or even its value from the reader's standpoint.

Electro-Chemistry, by R. A. Lehfeldt, professor of physics at the East London Technical College. 263 5 × 7-in. pages; 55 illustrations. Longmans, Green & Co. London. 1904. Price, $2.00. — This is the second volume published of the interesting series of contributions to physical chemistry promised by the publishers, and which are being prepared under the able editorship of Sir William Ramsay. The scope of this book

is very well outlined in the author's short preface: " The present volume deals with the general theory of electro-chemistry. This is divided into two parts, one giving the relation between quantity of electricity and quantity of chemical action; the other and more recent part forms the pendant to the first by giving the relation between electromotive force and intensity of chemical action. These subjects are dealt with in Chapters I and III. Chapter II is in the nature of an appendix to the first chapter, and may be omitted by those who are not interested in pure chemistry without detriment to the continuity of the book. In a subsequent volume it is hoped to discuss the most important applications of the theory to primary and secondary cells, to electrolysis, and to the solution of chemical problems." Chapter II has been written by T. S. Moore, lecturer in the University of Birmingham.

This book forms a notable addition to the literature on physical chemistry, and cannot fail to be warmly welcomed by all students of this important science. The typography, paper and binding are very satisfactory.

Elements of Applied Microscopy, by Charles-Edward Emory Winslow, instructor in industrial microscopy and sanitary biology in the Massachusetts Institute of Technology. 183 5 × 7-in. pages; 60 illustrations. John Wiley & Son. New York. 1905. Price, $1.50. — The most valuable characteristics of this little book are clearness and simplicity. As the author well says in his preface, it is intended for the teacher and the beginner with the microscope, not for the specialist. While necessarily incomplete from the standpoint of the expert in any of the branches which it treats, it conveys a very satisfactory idea of the possible applications of the microscope in various fields of applied science. It will, therefore, provide the student with the necessary foundation upon which he may build along his special line of work. To do this and to do it well deserves warm commendation. It is very satisfactory to find that the author has devoted a few pages to the application of the microscope to the examination of the structure of metals, seeing that this relatively recent but most important field of research is so persistently ignored in textbooks on microscopy. On page 163 the author writes that the study of the structure of metals with

the microscope owes its beginning to Dr. Early of Sheffield. This should read Dr. Sorby. We note with regret that the use of the vertical illuminator and of illuminating objectives for the examination of opaque objects is not mentioned.

The titles of the chapters are as follows: Function and Parts of the Microscope, Manipulation of the Microscope, The Mounting and Preparation of Objects for the Microscope, Micrometry and the Camera Lucida, The Microscopy of the Common Starches, Foods and Drugs and Their Adulterants, The Examination of Textile Fibers, The Microscopy of Paper, The Microscope in Medicine and Sanitation, Forensic Microscopy, Micro-Chemistry, Petrography and Metallography. The name of the publishers is a guarantee that the book is well printed and bound.

Elements of Mechanics, by Mansfield Merriman, professor of civil engineering in Lehigh University. 172 5 × 7-in. pages; 142 illustrations. John Wiley & Sons. New York. 1905. Price, $1.00. — The following interesting remarks are extracted from the author's preface:

"In the opinion of the author there should be given in every engineering college two courses in rational mechanics, — an elementary one during the freshman year, in which only as much mathematics is employed as is indispensably necessary, and an advanced one after the completion of the course in calculus. It is the principles and fundamental methods which are of the greatest value and importance, and if no course in mechanics is given until calculus has been completed, as is now generally the case, the student is introduced to a wilderness of algebraic matter in which these principles are largely obscured. Fortunately, the fundamental elements can be presented without such advanced mathematics, and this book is an attempt in that direction.

"To read this volume with interest and profit, only a knowledge of plane geometry, elementary algebra and plane trigonometry is required. It is intended for manual training schools, freshman classes in engineering colleges and for young men in general who have the preparation just indicated. To all who may use the book, it is strongly recommended that many numerical problems should be solved, and that in so doing

the actual forces and bodies should be always kept in mind with the principles that govern their relations. Forty lessons thoroughly mastered will form a solid substructure on which applied mechanics may safely stand. If this be accomplished and an advanced course be later pursued, as above advocated, it is believed that the interests of sound engineering education will be materially promoted."

The book is divided into seven chapters dealing respectively with Concurrent Forces, Parallel Forces, Center of Gravity, Resistance and Work, Simple Machines, Gravity and Motion, Inertia and Rotation. Each chapter is subdivided into articles, and each article is accompanied by ten well-selected problems, the book containing a total of 400 of these problems. The author's aim is admirably realized in this little volume, which we also find well illustrated and printed on good paper, with a substantial and attractive binding.

Mechanics Applied to Engineering, by John Goodman, professor of engineering in the University of Leeds. 730 5 × 7-in. pages; 714 illustrations. Longmans, Green & Co. London. 1904. Price, $3.00. — This is the fourth and enlarged edition of Professor Goodman's well-known book. The work is written especially for engineers and students who already possess a fair knowledge of elementary mathematics and theoretical mechanics. In the present edition some of the chapters have been considerably enlarged, namely, those on Mechanics, Dynamics of Machinery, Friction, Stress, Strain and Elasticity, Hydraulic Motors and Machines, and Pumps. The useful character of this book is greatly enhanced by the author's clear and thorough treatment, and by numerous, well-selected examples. It can be highly commended to all engineering students desirous of applying their knowledge of mechanics to practical engineering problems.

A Treatise on Friction and Lost Work in Machinery and Mill Work, by Robert H. Thurston. 430 5½ × 9-in. pages; 77 illustrations. John Wiley & Sons. New York. 1903. Price $3.00. — The fact that this is the seventh edition of this book is a conclusive evidence of the favor with which it has been received. In the present edition a considerable amount of new matter appears, and something in the nature of a summary has

been added, bringing the work up to date. The following titles of the chapters will indicate the scope of the book: Theory of Machinery — Its Action and Its Efficiency; Nature, Laws and Theory of Friction; Lubricants; Lubrication and Apparatus; Chemical and Physical Tests of Oils; Experiments on Friction and Testing Machines; Lubricated Surfaces, Coefficients of Friction, Modifying Conditions; The Finance of Lost Work of Friction; Recent Investigations and Conclusions. The author takes the stand that the apparent saving in quantity when using solid lubricants is more than offset by an increased loss of power, and he advocates the use of solid lubricants such as graphite, talc, etc., only for very heavy bearings driven at slow speed.

A Manual of Mining, by M. C. Ihlseng, formerly dean of the School of Mines of the Pennsylvania State College, and Eugene B. Wilson, mining and metallurgical engineer. 723 $6\frac{3}{4} \times 9$-in. pages; 337 illustrations. John Wiley & Sons. New York. 1905. Price, $5.00. — While this book is issued as the fourth edition of Dr. Ihlseng's well-known book, the first edition of which was published in 1891, the present volume has been so considerably enlarged and so extensively rewritten, chiefly through the coöperation of Eugene B. Wilson, a well-known mining engineer, as to make of it a new work. A notable addition to the present edition consists in an exhaustive treatment of coal mining in its various phases. There is also a valuable chapter written by R. W. Hutchinson on Electricity and Its Applications to the Mining Industry. The typography, illustrating, paper and binding leave nothing to be desired.

PATENTS

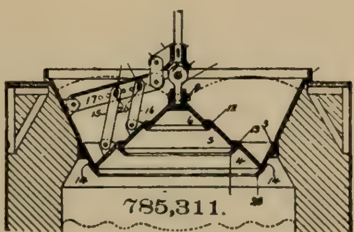
RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

785,002. Manufacture of Iron and Steel. — James J. Hudson, Philadelphia, Pa. An improvement in the art of manufacturing iron and steel, which consists in placing a combined charge of charcoal and the material to form such metal upon the hearth or bottom of a furnace, melting said metal with the charcoal, and maintaining a molten bath of the metal in contact with the charcoal until the completion of the heat.

785,210. Press for Compressing and Drawing Ingots in Conical Molds. — Henri Harmet, St. Etienne, France. In a press, two rams arranged to press in opposite directions upon the ingot within a conical mold, a plug connected with one of said rams and arranged to enter the smaller end of the mold to guide said mold in proper vertical position, a support or head carrying the ram to which the plug is connected, an abutment projecting below the head and surrounding the plug to form a space for the reception of the plug, and a washer arranged in the head above the plug and forming a limitation for the upward movement of the plug in said head.

785,311. Distributing-Bell. — James B. Ladd, Wayne, Pa., and David Baker, Newton, Mass. In combination with a chamber, a distributing-bell comprising a plurality of sections and means for causing the simultaneous movement of said sections relatively to the chamber and to each other.



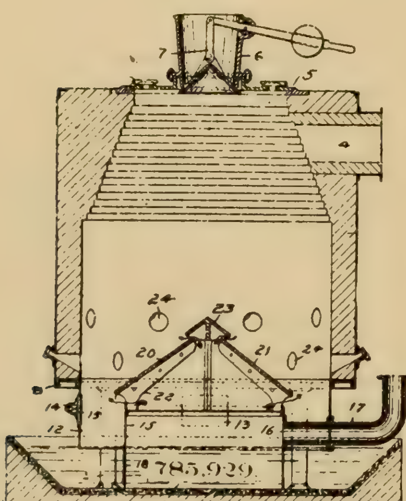
785,379. Electric Welding Machine. — Adolph F. Rietzel, Lynn, Mass., assignor to Thomson Electric Welding Company, Lynn, Mass. In an electric metal-working apparatus, the combination of a starting device for causing current to flow through the section of work to be heated, an automatic cut-off for stopping the flow of current through the work, means connected with the work-holder for bringing the cut-off into action when, by the softening of the work, said work-holder has been permitted to move to a predetermined extent, and means for resetting the cut-off device by readjustment of the starting device to position for placing the apparatus in condition in which no current will be supplied to the work.

785,630. Conveying Mechanism for Furnaces. William McClave, Scranton, Pa., assignor to McClave-Brooks Company. A convey-

ing mechanism comprising a duct, approximately U-shaped, in cross-section having a bottom formed with a central curved portion, and inclined side portions extending therefrom, and side walls extending upwardly from the inclined portions of the bottom, the side walls affording ample capacity for material above the conveyor, a conveyor moving in the duct, the said conveyor engaging only the curved portion of the floor, and means for operating the conveyor.

785,841. MATERIAL FOR FURNACE-LININGS. — Henry G. Turner, London, England. A process of heating magnetite in an electric furnace at the temperature of the electric arc to a point where the material crystallizes, cooling the resulting product, grinding the same and mixing it with a suitable binding material which will harden and cause the mixture to set.

785,929. GAS-PRODUCER. — Walter O. Amsler, Pittsburg, Pa., assignor to the Amsler Engineering Company, Pittsburg, Pa. In a gas-producer, the combination, with the combustion chamber having a series of poke-holes in the clinker zone, of a circular water-sealed trough below the combustion chamber, a cylindrical apron extending downwardly from the combustion chamber into the trough to a line below the water seal, having its inner surface in line with the line of the inner surface of the wall of the combustion chamber, and provided with a series of openings located adjacent to the lower end of the wall of the combustion chamber, said openings of sufficient size to permit the removal of clinkers therethrough, a standpipe of large area having closed sides, its lower end resting on the bottom of the trough and extending upwardly to a line intermediate of the lower end of the wall of the combustion chamber and the water seal, a fluid-supply pipe passing through the apron and in communication with an opening in the standpipe immediately above the water seal, a hood of large area above the standpipe formed of a series of non-perforated plates, means for supporting the hood above the upper end of the standpipe to form a fluid passage between the upper end of the standpipe and hood, and a non-perforated hood above the first hood supported so as to form a fluid-passage between the hoods.



785,955. GAS-PRODUCER. — Francis W. Johnstone, Mexico, Mexico. In a gas-producer, the combination, substantially as set forth, of a vertical fire-chamber, an open-bottomed retort depending therein throughout the major portion of its height, means for supplying fuel to the retort, means for raising fuel which passes out of the bottom of the retort into the surrounding fire-chamber space between the walls of the producer and the retort, and a gas-discharge pipe leading out of the upper portion of the fire-chamber.

786,009. Process of Casting. — Frederick Cowden, Montreal, Canada, assignor of one half to Robert Samuel Logan, Montreal, Canada. A process of casting metallic articles, consisting in causing the molten metal being cast to come into contact with an unprotected loose heap of granular substance adapted to change the chemical and physical properties of the portion of the molten metal coming into contact therewith.

786,032. System for the Combustion of Gas. — James A. Herrick, Philadelphia, Pa. In a system for burning gas, a gas-producer, means for introducing air and burning ungasified matter in the top of said producer, a furnace-chamber, a passage leading from said gas-producer to said furnace-chamber, a regenerator-chamber and a passage leading from said regenerator-chamber to said furnace-chamber.

786,048. Process of Purifying Pig Metals. — John B. Nau, New York, N. Y. A process of purifying and enriching metals, which consists in pouring liquid metal upon a mass of broken pieces of solid oxidizing material in such manner that the liquid metal will be broken up and descend in small streams through the spaces between and in contact with the pieces of oxidizing material, causing a bath of the liquid metal to accumulate, maintaining immersion of the oxidizing material in the bath, so that the bath fills the spaces in the immersed mass of oxidizing material for the period desired, and then separating the liquid purified metal from the oxidizing material.

786,061. Process of Regulating Air and Steam Supplied to Gas-Producers. — Harry F. Smith, Lexington, Ohio. The art of supplying steam and heated air to suction gas-producers, which consists in causing the air and water to be heated to pass through an air tube, interposing a vane in said tube to be acted upon and moved by the air as well as to control the water-supply by its movements, and heating the air and converting the water into steam and supplying the steam and air to the producer.

786,062. Grate for Gas-Producers. — Harry F. Smith, Lexington, Ohio. A grate for gas-producers having a flat grated top, smooth imperforate sloping sides, and a horizontal ledge or rim at its bottom.

786,063. Suction Gas-Producer. — Harry F. Smith, Lexington, Ohio. Means for supplying steam and heated air to suction gas-producers, consisting of a movable weighted water-holding vessel, provided with an orifice through which the water may be discharged; an air pipe; a vane in the air pipe, adapted to be moved by the action of the air thereon when passing into the pipe; connections between the vane and water-supply vessel, whereby by the movement of the former predetermined and constant supply of water may be discharged from the water-supply vessel into the air pipe, and means for heating the air and water to convert the latter into steam, and means for conducting the air and steam to the producer.

786,180. Cooling-Jacket for Blast Furnaces. — David Baker, Newton, Mass. In a blast furnace and in combination with the bosh-wall, a cooling-jacket surrounding the same and provided at its lower end with a horizontal flat annular plate forming a continuation of the

outer surface of the jacket, and having its edge terminating beyond the body of the furnace, said plate adapted to receive without interruption the water flowing downward over the exterior of the jacket and adapted to permit it to be discharged freely outward, and a receiving-trough sustained free of the furnace wall vertically beneath the discharge edge of the plate in position to receive the water flowing over said plate.

786,185. Process of Producing Metals and Alloys. — Henry S. Blackmore, Mount Vernon, N. Y. A process of reducing metal and producing alloys thereof, which consists in fusing an oxy compound of a metal or metals having greater affinity for oxygen than the metal desired, adding thereto an oxy compound of the metal desired with another metal, an alloy with which is sought, and subjecting the mass to the action of an electrolytic current capable of liberating the metals desired, and replenishing the mass with more metal oxy compound from time to time as the bath is depleted thereof by reduction.

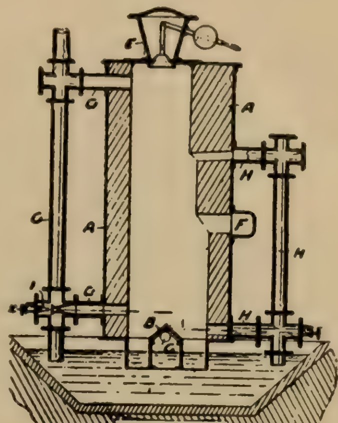
786,200. Gas-Producer. — Alfred B. Duff, Pittsburg, Pa. In combination, a gas-producer, a water-sealed ash-trough therefor, an air-receiving casing in the ash-trough, substantially vertical gratings carried on the casing and distributed over a large area, a free space for the fall of ashes between the air casings and producer walls, a louvered cone superimposed on the gratings, said cone consisting of a louvered ring of the casing, and a cover superimposed thereon so as to leave air space in the wall of the cone, said air spaces in the cone and grating being so proportioned that a sufficient quantity of air is made to act on the upper part of the fuel and light that part up to incandescence, while the lower grating causes the air to act upon such ignited fuel as it descends with a finer distribution and without raising the temperature at any point too high.

786,248. Casting. — Frederick Cowden, Montreal, Canada, assignor of one half to Robert Samuel Logan, Montreal, Canada. A cast manganiferous steel article, a portion whereof contains a higher percentage of carbon than the remainder, such portion also containing a higher percentage of manganese than the remainder.

786,359. Process of Perfecting Cast-Steel Ingots. — Robert W. Hunt, Chicago, Ill. An improvement that consists in first casting molten metal in a metal ingot mold or chill, and through the medium of said mold immediately initiating the solidification of the external portions of the ingot mass, and simultaneously therewith, by the introduction of a relatively small bar or rod of like metal, initiating and forcing the solidification of the axial portion of the ingot mass, thereby creating from and in the ingot mass an initially small but increasing solid column of denser metal, which later occupies the center of the ingot and prevents the development of a central pipe therein, permitting the ingot to cool in the mold until it becomes self-sustaining, then stripping the mold from the ingot and then heating the ingot.

786,365. Non-Oxidizing Annealing Furnace. — Charles F. Kenworthy, Waterbury, Conn. An annealing furnace comprising a retort, seals at each opening thereof, discharge and delivery means operating in

said seals and which are rotatable in a horizontal plane, and means other than the delivery means for transmitting material from the delivery means to the retort.



786,474.

786,474. GAS-PRODUCER.—Charles Whitfield, Kettering, England. The combination in a producer of the character indicated of a vapor-circulating pipe and an injector therefor worked by steam, for drawing off the lighter hydrocarbon vapors from the upper part of the producer and introducing the same into the incandescent fuel above the zone of combustion, and another vapor-circulating pipe and an injector therefor, worked by steam, for drawing off the less volatile or heavier hydrocarbon vapors and reintroducing the same into the incandescent portion of the fuel at the zone of combustion.

786,561. STEEL. — Robert A. Hadfield, Sheffield, England. A steel containing carbon, manganese, nickel and chromium (the percentage of manganese being low), and possessing a high elastic limit and a high tenacity with great ductility and toughness.

786,565. ANNEALING-FURNACE. — Johnson Hughes, Wissahickon, Pa. In an annealing furnace, a heating chamber, a plurality of sets of rollers for carrying the materials in said chamber, and means for operating said sets of rollers together or separately.

786,573. APPARATUS FOR SPRAYING BLAST-FURNACE CINDER. — Wilhelm Lessing, Geseke, Germany, assignor to Gesellschaft für Trockenzerstanbung Flussiger Materien mit Beschrankter Haftung, Berlin, Germany. In apparatus for spraying molten cinder, the combination, with a rotatable drum provided with ribs or fans which spray the cinder and circulate the air, of an inclosing casing for the said drum having an air inlet opening in its side at one end of the drum, and having also an opening above the drum, and a chute for supplying the cinder to the drum which projects through the last said opening.

786,770. SIEMENS REGENERATIVE FURNACE. — Adalbert Kurzwernhart, Zuckmantel, near Teplitz, Austria-Hungary. A method of forcing the combustible gas into Siemens regenerative furnaces, wherein, before the reversing operation, the gas contained in the regenerative chamber, after being cut off in any known manner from its source of supply, is introduced into the furnace by flue or waste gas, the said flue or waste gas being displaced from any flue or chamber containing such gas and caused to move through the gas-supply passage into the regenerative chamber.

786,923. PROCESS OF FORMING TUBES. — Lester C. Smith, Rome, N. Y. A process of forming a tube from a strip of sheet material in four operations, which consists, first, in turning in the edges of the strip to a curvature substantially that of the circle of the completed tube; second, in bending the strip along the middle to a curvature less than that of

the circle of the completed tube; third, closing the tube into an oval form with the meeting edges in the large end of the oval, and fourth, forming the last-mentioned form into a circular form.

787,222. Reversing-Valve for Regenerative Furnaces. — Josef Reuleaux, Wilkinsburg, Pa., assignor to Alexander Laughlin, Sewickley, Pa. In a reversing-valve, in combination, an upper supply-casing, a lower outlet-casing, upper and lower seal-troughs for such casings, two cylindrical valves working in said seal-troughs and through which the gases pass from the supply-casing to a regenerative flue, or which permit the gases to pass from one regenerative flue to the outlet-casing, means for moving the valves lengthwise, and means for maintaining the integrity of one seal of each valve during the movements of the valves.

GREAT BRITAIN

4,122 of 1904. Furnace Charger. — K. Backlund and B. F. Burman, Baltimore, Md., U. S. A. Apparatus for charging a series of metallurgical furnaces by means of only one hoist.

10,902 of 1904. Purifying Steel. — Société Anonyme pour l'Industrie de l'Aluminum, Neuhausen, Switzerland. Improved process for reducing any oxide of iron that forms in steel or ingot iron.

29,093 of 1904. Coating Steel. — E. Jabulowsky, Pforzheim, Germany. Producing a surface of black oxide on steel articles by heating them in carbon powders and afterwards polishing.

27,991 of 1904. Refractory Material. — D. B. Williams and J. R. Stauffer, Washington, D. C., U. S. A. Making a highly refractory material by subjecting clay to great heat while enveloped in incandescent coke.

28,491 of 1903. Utilizing Heat in Open-Hearth Furnaces. — Cammell, Fletcher & Hamilton, Sheffield. In the manufacture of steel, using the waste heat from the converter for preliminarily melting the iron in an open-hearth furnace before it is charged into the converter.

4,557 of 1904. Utilizing Slag. — T. Twynam, Leeds. Improved method of utilizing iron slags for making artificial stone, etc.

6,021 of 1904. Steel for Crushers. — S. Osborn, Sheffield. Making the crushing surfaces of jaw-breakers of ribs of special steel, such as tungsten, or manganese steel.

24,175 of 1904. Nickel Steel. — A. de Dion and G. Bouton, Paris. The addition of from 0.5 to 2 per cent of silicon to nickel steel in order to increase its strength.

5,041 of 1904. Smelting Furnace. — M. Moore and T. J. Heskett, Melbourne, Australia. A continuous furnace for smelting iron sands by the action of carbonic oxide or hydrocarbon gases.

25,948 of 1904. Electric Furnace. — Société Electrometallurgique Francaise, Froges, France. Improved electric furnace for manufacturing steel from mixtures of cast iron and scrap iron and steel.